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ABSTRACT

To assist higher education facility officers in documenting their financial needs for renewing and renovating existing physical facilities, this study examined the accuracy against observed conditions of the tools used to identify vertical infrastructure maintenance needs in a large public university. Data developed for U.S. Army facilities is utilized in three different ways to identify whether such data will be accurate in higher education facilities. The application methods explored are selected to utilize as much data as possible that is familiar to non-technical people while still providing a reasonable reflection of changing annual needs. The selected funding needs model is accurate within 10 percent, a similar level of error when compared to the physical assessment techniques used. The model is also useful for planning purposes to identify future resource needs and documenting costs for overhead charges. Appendices contain a building maintenance database report and building evaluation form. (Contains 84 references.) (GR)

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HIGHER EDUCATION
VERTICAL INFRASTRUCTURE
MAINTENANCE PLANNING

By

Theodore J. Weidner

A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

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ABSTRACT

A major concern facing American higher education is finding the resources necessary to renew and renovate the existing physical facilities. Pressure on budgets makes it difficult for facility officers to obtain the needed financial resources without documentation that is understandable by non-technical people. Renewed growth of student populations has the potential to make future deferred maintenance problems greater still. The cyclic nature of building maintenance must also be reflected in resource requests.

Tools to identify vertical infrastructure maintenance needs are examined for accuracy against observed conditions at a large regional public university. Data developed for US Army facilities is utilized in three different ways to identify whether such data will be accurate in higher education facilities. The application methods explored are selected to utilize as much data as possible that is familiar to non-technical people while still providing a reasonable reflection of changing annual needs. The selected model is accurate within ten percent, a similar level of error when compared to the physical assessment techniques used. The model is also useful for planning purposes to identify future resource needs as well as to document costs for overhead charges.

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ABSTRACT

A major concern facing American higher education is finding the resources necessary to renew and renovate the existing physical facilities. Pressure on budgets makes it difficult for facility officers to obtain the needed financial resources without documentation that is understandable by non-technical people. Renewed growth of student populations has the potential to make future deferred maintenance problems greater still. The cyclic nature of building maintenance must also be reflected in resource requests.

Tools to identify vertical infrastructure maintenance needs are examined for accuracy against observed conditions at a large regional public university. Data developed for US Army facilities is utilized in three different ways to identify whether such data will be accurate in higher education facilities. The application methods explored are selected to utilize as much data as possible that is familiar to non-technical people while still providing a reasonable reflection of changing annual needs. The selected model is accurate within ten percent, a similar level of error when compared to the physical assessment techniques used. The model is also useful for planning purposes to identify future resource needs as well as to document costs for overhead charges.

CHAPTER 1

INTRODUCTION

A major concern facing American higher education is finding the resources necessary to renew and renovate the existing physical facilities. This is a particularly serious problem at public universities because of financial pressures on state budgets. Over the years, following the "golden age" of higher education (when facilities expanded to meet the demands of a rapidly growing student population) budget restrictions have resulted in the postponement of replacement capital equipment or major repairs to constructed facilities. Fixed building equipment such as chillers, pumps, and fans are repaired to keep them working despite age and need for replacement. In addition, new equipment which can provide opportunities for significant improvements in energy efficiency and technology are not purchased. This delay in replacements and/or upgrades of building equipment or components is typically described as capital renewal/deferred maintenance (CRDM).

As student populations continue to increase, restrictions in state budgets postpone the construction of new facilities. This results in heavier use of existing facilities and an increased rate of decay. Institutional administrators are often unfamiliar with the technical complexity of campus facilities and uncomfortable in providing the funds necessary to protect existing facilities. In addition, when funds become available for new facilities, there is little understanding of the future costs to preserve physical assets so they retain their value. The multi-year expenditure of a significant percentage of building replacement cost to preserve a building seems antithetical to prudent practices.

This study analyzes major maintenance funding needs for higher education facilities. It presents budgetary tools which have been developed over the past fifteen years. It presents a technique to plan for major maintenance expenditures in higher education facilities which does not rely on technical expertise or knowledge of individual building components. The technique used relies on data which is familiar to institutional administrators and planners. It also provides the administrator with the means to predict, several years in advance, the varying needs for facility maintenance.

The data used consists of academic space types (classrooms, laboratories, offices, etc.), age, and a schedule of values deduced from United States Army facilities to arrive at a system which is relatively simple and which predicts varying expenditures for major maintenance on an annual basis. This method eliminates the need for detailed architectural or engineering information which is difficult for non-technical faculty and administrators to understand and manage. Because the method is related to academic information, it can also be used to assess the cost and value of an academic or research program in more quantifiable terms.

1.1 General Overview

The issue of deferred maintenance at colleges and universities came to the forefront in 1987 with the publishing of a joint article and video by APPA (the Association of Physical Plant Administrators, now called the Association of Higher Education Facility Officers) and NACUBO (National Association of College and University Business Officers) entitled "Deferred Maintenance: the ticking time-bomb". In the video a number of serious deferred maintenance problems were highlighted as well as their costs. The video was produced to highlight to boards of trustees and administrators many of the facility problems they were ignoring (or assuming would just go away).

The video also had its roots in several books by Harvey Kaiser, Ph.D., for APPA in 1979, 1982, 1984, and 1987. In the *Facilities Audit Workbook*, 1987, Kaiser created a general outline to assess and compute the amount of deferred maintenance in any facility. This outline is one of several assessment tools for facilities developed over the years and will be discussed in further detail later.

The issue of deferred maintenance is significant for colleges and universities for several reasons. Most colleges and universities are permanent, they typically have not moved from their original location, or have not moved for over 50 years (the typical assumed life of a building). Depending on the type of college or university, there is a high demand for constructed facilities and space in order to perform instruction, research, and service. Very few colleges or universities exist as logical entities alone, there is a physical presence. The primary producers of education are not facilities but faculty, hence the value of a college or university is seen in the academic credentials of the faculty and not in the condition of the facilities. However, few faculty have the ability to work without sophisticated resources found in higher education facilities. This dichotomy is part of the basis for existence of accumulated deferred maintenance (ADM) in higher education.

The colleges and universities referenced in this study are non-profit institutions which rely on outside funding for more than half of their operating and capital costs. Because they are non-profit, they do not follow accounting approaches used by for-profit businesses to depreciate the value of facilities. GASB, the Government Accounting Standards Board, indicates that "depreciation of general fixed assets should not be recorded in the accounts of governmental funds." Recent recommendations and applications of depreciation methods among private colleges and universities have led to increased financial concerns and potential differences between private and public universities. Public universities can not depreciate or capitalize facilities in accordance with the GASB rule. The lack of a capitalization technique for physical facilities has delayed addressing the costs associated with major maintenance activities.

Deferred maintenance, and the concept of scheduled maintenance is not foreign to the Civil Engineering field. Numerous theses and studies into maintenance of pavements have been developed over the years, particularly at Purdue University and MIT. More recently the maintenance needs of highway structures, bridges and pipe lines (water, sewer, gas and conduits for wires), have become subjects of study. In these works the rate of wear and levels of maintenance is compared with the costs, among other factors, to identify an optimal maintenance level and the optimal maintenance activity. Articles in *Civil Engineering* magazine, September 1994, address deferred maintenance for public infrastructure. The United States Army, which has numerous, large, long-lived facilities, has conducted studies to determine optimal maintenance activities through its Construction Engineering Research Laboratory. Similar studies are required for college and university buildings because of their longevity, in order to identify optimal maintenance activities and to fund adequately those maintenance activities through proper budgeting. The *Journal of Infrastructure Systems* by the American Society of Civil Engineers, was established in 1995 to highlight research in this area. Articles appearing in this publication have focuses primarily on highways and pipelines (horizontal infrastructure) and not on buildings (vertical infrastructure) for human habitation. Therein lies part of the motivation for this study.

This dissertation will present several measurement tools for capital renewal expenditures. It will attempt to show how non-linear concepts of maintenance budgets and maintenance activities can be applied to college and university buildings. It will look at several facility maintenance budgeting tools, comparing and contrasting those tools with the relative accuracy at predicting funding needs. It will identify a simple means, using data that is familiar to higher education administrators, to determine long term major maintenance funding needs for colleges and universities. It will look at the life cycle cost of building components and measures to adjust the recurring costs through other means.

This will be done by examining the planning and facility records of Eastern Illinois University. These records, it is believed, identify the kinds of maintenance necessary to maintain facility asset value initially, identify a history of major maintenance requests and funding authorizations (the difference between which will identify the deferred maintenance), and characterize a path of building condition through the accumulation of deferred maintenance. Use of several different models on the data will provide comparisons against each model and observed conditions to identify the applicability of the proposed model.

1.2 Study Subject

This section provides a review of the issues relevant to this study. It begins with a review of the components of a typical higher education building, the factors which limit the life of the building, and the means to influence those factors to extend component life. It also examines the various accounting techniques developed to enumerate major maintenance and renewal and describes the relationship to actual limitations of component life based on maintenance factors. Facilities at the Eastern Illinois University campus will be used as representative facilities of colleges and universities.

The subject institution was founded in 1895 as Eastern Illinois Normal School. The institution has had four names which changed to reflect the character of the institution and its goals. Since 1957 it has been known as Eastern Illinois University (EIU). In 1997 it is composed of four colleges: Business and Applied Sciences, Education and Professional Studies, Arts and Humanities, and Science. Eastern is a Carnegie Comprehensive II campus serving about 11,000 students and with 1,800 faculty/staff in a residential setting. Approximately 60% of the student body lives on campus, one of the highest rates of residency for a public university. It is comprised of 3 million square feet of space on 320 acres of land. Educational and general (state supported) facilities generally are between 1 and 4 stories tall. These buildings are between 5 and 100 years old and average 40 years old. The bulk of the buildings were constructed in the 1960's. A few structures are load bearing stone/masonry, most are steel frame although there are some concrete frame structures. Most buildings have central air-conditioning; hot-water and steam radiation are prevalent in older buildings. The central power plant provides steam to the campus utilizing any of three fuels, coal, oil, or natural gas. A water tower on campus insures sufficient water pressure from the city's system to meet campus needs.

Dormitories, apartments, fraternity/sorority houses, and the student life areas were constructed with bonds paid through revenue generated by rents and student fees. These buildings range between 2 and 10 stories and average 20 years old. They are better maintained due to legal commitments to bond holders to preserve the capital value and to maintain sufficient appeal to keep them fully occupied. These facilities are omitted from this study for reasons of clarity, financial structures, and access to historic information.

The buildings constructed in the 1960s were generally designed by the same architectural and engineering firms. This is typical in Illinois, the 39 campus community college system was designed by predominantly four firms, Aldrich (1993). This uniformity of design, in materials and construction features makes a generally harmonious campus appearance and provides an overall unifying influence. The uniformity of design has also contributed to the congruence of building life limitations and accumulated deferred maintenance (ADM).

Another feature affecting building life has resulted as an overall lack of supervision of designers and contractors by the university. The buildings are difficult to maintain. Equipment is difficult to reach, is exposed to nature with many roof-top mechanical systems, and has features which are prone to obsolescence. These factors have hastened the decay and shortened the life of some equipment and led to an overall degradation of the facilities. Appropriate maintenance, including periodic investment in facility replacements, would have reduced the accumulation of deferred maintenance.

One of the major concerns facing American higher education today is finding the resources necessary to renew and renovate the existing physical plant. This problem is considered a result of what is often referred to as higher education's golden age, a period extending from the 1950's to the 1970's when a great deal of money flowed to universities to construct new facilities to handle a large student population. As a result, higher education presidents and governing boards are now faced with the need to obtain the funds required to renovate the facilities created during these decades. The demand for renovation and rehabilitation creates at least two problems for facility managers and administrators in colleges and universities. One is to obtain the funds necessary for renovation and rehabilitation activities. The other is to reduce the funds provided to other areas of institutional operations. Both of these are difficult courses of action to follow in a financial environment characterized by stable or declining revenues, demands for accountability of public funds, and pressure to reduce overall tax loads on citizens. This study recognizes that while techniques exist to generate additional funds, most are outside the control of facility officers. The techniques which are within the facility officer's control, primarily energy related, are a separate research area and are not discussed here.

The second problem faced by administrators is to determine for any given period of time the appropriate level of funding for renovation and rehabilitation of existing physical plant facilities. Too many funds allocated to the physical plant will result in the underfunding of other areas of the budget such as faculty salaries, support services, grants or research activities. Conversely, the underfunding of an institution's physical plant will add to an increasing backlog of deferred maintenance as well as renovation and renewal requirements. The result will be facilities which cannot support the essential activities of the institution. This is exhibited in spaces in which facilities are used inappropriately because no funds were available to renovate a space when needs change and/or the original equipment within the facility no longer provides reliable service for building occupants and/or is too expensive to keep operational through annual maintenance activities. This problem is exacerbated by the fact that renovation and renewal requirements are cyclical in nature and may not lend themselves to a linear funding system. As a result, for the decision maker, the challenge is not only how much to fund but the timing of this process as well.

1.3 Research Approach

This study will attempt to answer two primary questions facing higher education administrators when addressing major maintenance expenditures. First, is there a previously existing model or dataset which can be used as a predictive maintenance model for college and university facilities? Second, can a relatively simple model, based on planning level information, managed and understood by a non-engineering or non-architecture administrators and academics, be applied to existing university data to reasonably predict annual expenditures for major maintenance in the future? These funding predictions will allow planners and administrators to weigh the future costs of different types of academic space against each other as well as use the information to make funding predictions for existing facilities.

1.4 Summary

The first chapter has introduced the overall problem facing colleges and universities regarding deferred maintenance of physical facilities. It has identified problems of poor coordination between instructional/research/service cost needs and facility maintenance cost needs as contributing to deferred maintenance levels; the size of facility renewal costs when tackled at once result in major reallocations from other important areas of the university.

The second chapter will present detailed information about accumulated deferred maintenance (ADM) in colleges and universities. It will present definitions and fundamental measures that will be used in this study. It will identify the development of deferred maintenance as a subject of study and why it is a problem in higher education. It will also identify numerous studies and present models or recommendations on planning major maintenance for funding the reduction of ADM. The models will be discussed briefly and the principle models for this research will be identified.

The third chapter will investigate the models identified in Chapter 2. It will describe the models in detail, present their historic, economic, or engineering bases and will identify how they can be applied to the study institution. The data of the study institution will also be presented and described. These data include information on the historic nature of the campus, its development since its founding, funding over forty-two years, and initial information on the state of the campus as predicted by the models.

The Chapter 4 will apply the models to the study institution. It will compare the results of the different models and validate the models through review against empirical data. It will also compare the recommendations of the models with the actual expenditures over a forty-two year period to determine if the physical evidence could have been predicted by the models. Models thus validated will then be used to make predictions for the future to identify funding needs to preserve the campus. They will make predictions on the state of facilities when they reach the end of their original design life and make predictions of their modified design life resulting from facility expenditures.

Finally, the fifth chapter will summarize the results of the study, make conclusions and recommendations based on the analysis of this study and make recommendations for further study in the problem of deferred maintenance in higher education.

CHAPTER 2

HISTORICAL REVIEW

2.1 Introduction

This chapter provides a historical review of the issues relevant to this study. It begins with a review of the historical growth and development of the higher education physical plant, and the factors which have influenced the expansion. Definitions and fundamental measures for higher education maintenance are presented. It presents the factors which contributed to the rise of deferred maintenance in higher education today. The use of depreciation of capital in higher education is reviewed as are the foundations and use of formula funding in higher education. The use of empirical data gathering for funding predictions, as well as the use of empirically based systems will also be reviewed. The chapter concludes with a description of the models which have been proposed as methods for estimating renovation and renewal requirements.

2.2 Growth and Development of the American (US) Higher Education Physical Plant

Several factors have contributed to the current status of capital renewal requirements of American higher education. One of the most significant of these factors is the historical development of the university physical plant itself. The growth of higher education, particularly from 1950 to 1970, was responsible for a tremendous overall increase in the size of the higher education physical plant. Rush and Johnson (1989) note that since 1950, physical space on college and university campuses has increased by 400 percent. They also observe that the gross square footage of facilities constructed from 1950 to 1975 exceeded the amount of space constructed in the previous 200 years. It was estimated that in 1988, higher education physical facilities totaled at least 3 billion gross square feet, and perhaps as much as 3.4 billion gross square feet (Rush and Johnson, 1989). More recent estimates for this metric are put at 4 billion gross square feet (Kaiser & Davis, 1996).

The growth of higher education facilities was driven by several factors. One of these was the increase in the number of students attending higher education institutions. Between 1870 and the late 1970's, enrollment in higher education increased at an average annual rate of 5 percent according to The Carnegie Council on Policy Studies in Higher Education (1980). By comparison, the average annual rate of population increase for the same time period was 1.6 percent. The "baby boom" is attributed with much of the increase as well as several federal programs supporting higher education. The first federal program to assist students to enroll in higher education was implemented by the National Youth Administration from 1935 to 1943. This program expended $93 million and assisted 620,000 students (Brubacher and Rudy, 1976). The GI Bill, started after World War II, made participation in higher education possible for a much larger proportion of the population than ever before. Subsequent programs providing low interest loans and savings programs have continued to support the demand for higher education.

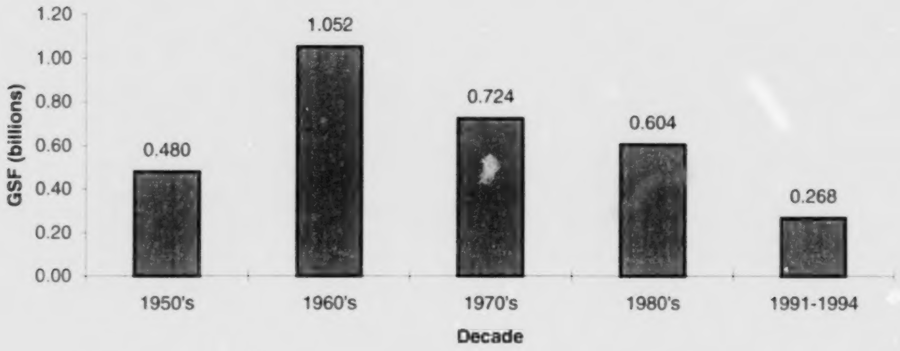
The federal government affected the growth of higher education facilities in other ways. Brubacher and Rudy (1976) noted that "the impact of the Second World War led Washington to assume 83 percent of the nation's total research budget in the natural sciences. By 1950 a dozen or more federal agencies were spending over

$150,000,000 a year for contract research at various American colleges and universities" (p. 231). Rush and Johnson (1989) also note that expenditures by the National Science Foundation increased from $300 million in 1955 to $3 billion in 1974. Construction costs increased during this period by 2.5 times (Means, 1995), resulting in a net increase of 400%. Expanding research expenditures were not the only area of federal activity which had an effect on the growth of higher education facilities. The Surplus Property Act of 1944 provided higher educational institutions with large quantities of supplies and buildings at minimal or no cost. Beginning in 1950, the federal government also provided long term loans to colleges and universities for the construction of dormitories though the Housing and Home Finance Agency. By 1962, this agency had loaned over two billion dollars to higher education institutions (Brubacher and Rudy, 1976).

The growth of higher education facilities can be examined from a variety of perspectives. One way is to chart the space increase. From this standpoint, growth has been rapid and significant. Figure 2.1 shows the growth of higher education gross square footage over the past forty-five years.

FIGURE 2.1

CONSTRUCTION OF UNITED STATES
CAMPUS SPACE
1950 TO 1994

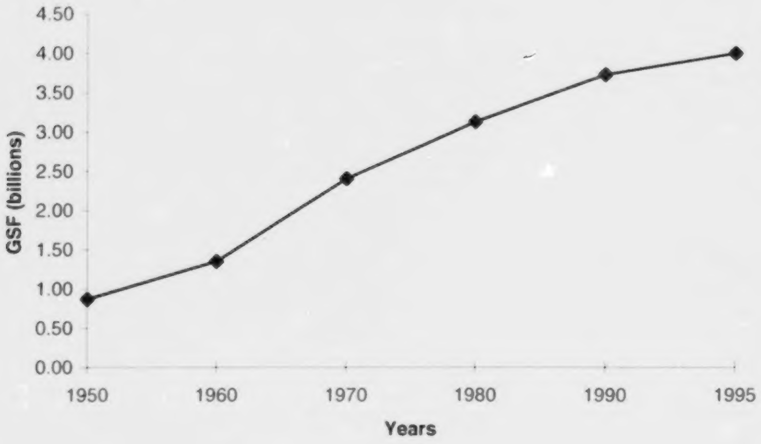


Source: Harvey Kaiser & Jerry Davis, A Foundation to Uphold, p.27

Rush and Johnson (1989) also point out that growth has not been constant, but concentrated, primarily in the decades of the 1960's and 1970's. Figure 2.1 demonstrates that over one billion gross square feet of space was constructed from 1961 and 1970. This is more than twice the amount constructed in the previous decade. Figure 2.2 shows the total campus area with a steep increase occurring in the 1960's.

FIGURE 2.2

GROWTH OF UNITED STATES CAMPUS SPACE
1950 - 1994



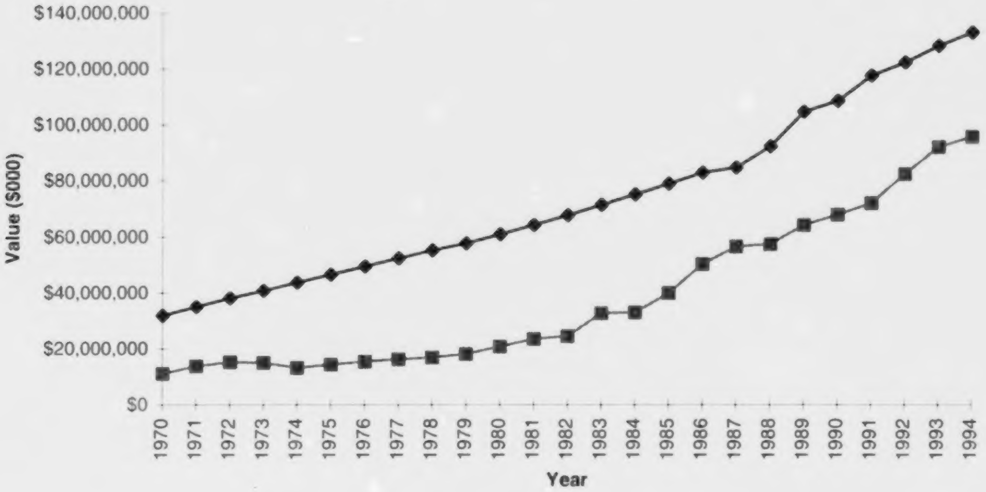
Source: Harvey Kaiser & Jerry Davis, A Foundation to Uphold, p.27

The higher education physical plant is a capital asset, a fact often forgotten or ignored by university administrators when addressing academic and financial issues. From this viewpoint the value of the higher education infrastructure is no small issue. Silverstone (1990) points out that in independent colleges and universities, investment in physical plant accounts for approximately 40 - 60 percent of total assets. The facility infrastructure at public colleges and universities represents an even larger portion of campus assets due to generally smaller endowments. By comparison "only about 25 percent of the assets of the typical large American business corporation are invested in plant" (p. 2). A comparison of the historical growth of building assets and endowment value in higher education indicates the significance of the campus infrastructure as a capital asset. From the early 1900's to the late 1930's, the value of buildings and endowment were nearly equal. By the

1950's, vertical infrastructure value had grown to twice that of endowment, Figure 2.3. The ratio between buildings and endowment peaked between 1974 and 1979 with buildings exceeding endowment value by more three times. Since that time the trend is gradually changing. Building value continues to increase at a rate which keeps it significantly above the value of the endowment but now it is only about one and one-half times more valuable. Figure 2.4 displays this relationship over time.

FIGURE 2.3

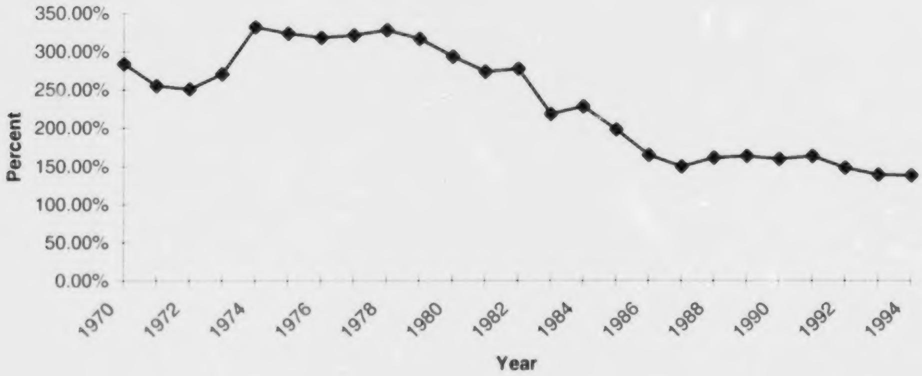
COMPARISON OF THE VALUE OF HIGHER EDUCATION
PHYSICAL PLANT AND INSTITUTIONAL ENDOWMENT
1910 TO 1994



Source: Digest of Educational Statistics, 1996, p. 350

Figure 2.4

RATIO OF VALUE OF HIGHER EDUCATION
PHYSICAL PLANT TO INSTITUTIONAL ENDOWMENT
1970 TO 1994



This rate of expansion generated concern regarding the need for funds to support renovation and rehabilitation, as well as maintenance activities for the existing physical plant. Jenny and Wynn (1970) called attention to the history of physical plant-growth, and noted the affect this would have on the need for accelerated plant maintenance and rehabilitation funding in the future. They also observed that they saw little indication that these needs were being anticipated. Albright (1982) noted several factors which would shape the way future renovation and renewal needs would be addressed. One of these factors is that two-thirds of the space existing in the 1980's was constructed during the 1950's and 1960's. A second factor is that most buildings have a restoration cycle of 20 - 30 years. She argued, therefore, that it was reasonable to assume that there would be significant renewal requirements for the existing buildings in the 1980's. Exacerbating the demands for funds to renew existing facilities was a restriction in overall campus funding, Kaiser (1976) which resulted in cut-backs in maintenance of facilities. Facility managers were required to rein-in budgets but struggled with the priorities of what not to do. Thus several characteristics of the higher education physical plant have all combined to create a situation of increasing capital renewal requirements.

2.3 Definitions and Measures of Maintenance in Colleges and Universities

Several definitions are presented here which will be used throughout this study. The source of each definition is identified and any deviations from other sources are clarified. The measurement of each term is identified and a brief discussion is provided.

2.3.1 Vertical Infrastructure

The physical plant of buildings comprising a college or university campus. Vertical infrastructure is composed of many different components to make the building. The different components each perform specific and unique functions within the building and must work together to form the entire building. Typical components comprising a vertical infrastructure include: a foundation and structure (both sub and super) to support the building; an envelope of exterior walls, windows, doors and roof which keep the weather out; circulation consisting of stairs, elevators and corridors which are separated from occupied spaces by interior walls; electrical systems providing light, power, communications and alarms; plumbing systems providing water for domestic, sanitary, and fire protection purposes; and mechanical systems providing heating, cooling, and ventilation which keep the facility comfortable during the different seasons.

Vertical infrastructure is different from horizontal infrastructure which is typically characterized by uniform, non-interrelated buried or surface systems such as water distribution piping, power transmission cables (either buried or suspended by poles or lattice towers), and pavements consisting of roads, bridges, and tunnels for vehicles and pedestrians. These elements are not interrelated in that a broken water distribution system does not automatically affect the delivery of electrical power to the same service area. The interruption of water service does not result in the inability of facility users to traverse roads or bridges.

In a vertical infrastructure interruption of a service results in a partial closure of the facility because other services are non-operational. A broken water line immediately damages interior partitions and surfaces, threatens the operation of electrical equipment and may result in a partial evacuation of the building. The lack of a building envelope prevents the effective delivery of heated or cooled air, making the facility uninhabitable during temperature extremes.

2.3.2 Annual Maintenance

Annual maintenance is the systematic day-to-day control of deterioration of facilities, vertical infrastructure. It includes periodic scheduled work also known as preventive maintenance which provides adjustment, cleaning (non-housekeeping), minor repair, and routine inspection of equipment intended to reduce service interruption. It also includes call-in requests for service such as damage repair resulting from vandalism or accidents, minor unplanned repairs, and repairs resulting from service interruption.

Some texts refer to this as *normal maintenance* and also include repetitive activities such as housekeeping, groundskeeping and site maintenance (Dunn, 1989). Other texts (Neathammer & Neely, 1994) specifically exclude housekeeping and groundskeeping from the definition of maintenance. These "maintenance" items are excluded in this study because they are not directly related to the preservation of the vertical infrastructure of a campus and cannot be measured using standard construction cost indices for labor and material expenditures.

2.3.3 Deferred Maintenance

This is the identifiable backlog of major maintenance projects unfunded in operating budgets and deferred to a future budget cycle (Dunn, 1989). A major maintenance project is either a maintenance project resulting from the underfunding of annual maintenance needs or the replacement of a building component when it has reached the end of its useful or predicted life cycle. An example of an annual maintenance project not performed as a result of underfunding is the replacement of decorative wood columns at a building entrance because they were not painted on a regular basis and became rotted and unstable. Examples of major maintenance projects include: roof replacements, replacement of a mechanical system or components such as chillers or pumps, and fixture replacements of a lighting system. When any of these are not funded in the specified or planned year, then the backlog of maintenance projects increases and the deferred maintenance increases. Deferred maintenance is reduced by funding, and performing, the major maintenance projects as described above. Deferred maintenance can increase annually as the cost of labor and/or materials used in construction increase due to inflation. It also increases as a result of secondary damage caused by maintenance that is not done.

In Illinois, major maintenance projects are referred to as "SR^3: Space Realignment, Renewal, and Replacement". This is based on the work of Harlan Bareither (1981) and applied by the Illinois Board of Higher Education. As Kaiser and Davis (1996) indicate, "there is no substantive difference between the terms [deferred maintenance vs. renewal and replacement]. The differences ... may be due to accounting practices that distinguish between annual operating budgets and projects that are treated as *capitalized* ...". This is the case in Illinois where each university requests funds for

SR^3 projects on the capital budget which is separate from funding requests for operations and maintenance (O&M) on the operating budget.

In this study, deferred maintenance is that major maintenance work which has either been identified as required as a result of life-cycle recommendations or as a result of a facility inspection.

2.3.4 Renovation

This is the changing of a portion of the vertical infrastructure for a specific purpose, to modernize or for a specific program requirement (Kaiser & Davis, 1996). An example of a renovation is the refitting of a laboratory or office from a biological research project to a ceramic engineering research project. In the former case, significant plumbing may be required for care and dissection of specimens while the latter case may require significant gas piping or electricity for heat generation. Renovation can also include the non-essential performance of major maintenance. An example is repainting of an office for a new occupant or replacement of carpet before it is fully worn to compliment a new wall paint color.

2.4 Fiscal Stress in Colleges and Universities

Overall financial condition is a second major factor which has affected the ability of colleges and universities to respond to the increasing needs of physical facilities. A variety of terms have been used to describe this situation, financial difficulty, financial health, and financial distress (Collier, 1982). In general, whatever the term used, the fiscal health of higher education has been perceived as declining.

One of the first terms used in this context was financial difficulty (Cheit 1973). The term described a fiscal situation which prevented the achievement of goals set by the administrators of the institution. A second definition of financial condition was proposed by the National Commission on the Financing of Higher Education (1973). The definition focused on the lack of resources within higher education which might prevent the accomplishment of national objectives. A third definition focused on the degree to which an institution faced closure. This definition attempts to draw a parallel between closure and the condition of bankruptcy or receivership in the private sector (Collier, 1982).

However it is described, there are a variety of causes for financial distress in higher education. Campbell (1982) found the primary causes to be "legacies from the period of growth, spiraling costs of inflation, and the costs associated with government-mandated social programs and government regulation" (p. 9). The last of these is now referred to as unfunded mandates. Glenny (1973) described four social and economic trends which have had an effect on higher education: the leveling of the proportion of government aid allocated to higher education, particularly by state governments; the development of new social priorities which have resulted in higher education losing its previously favored position within the governmental funding process; the shift of government aid away from categorical programs which provide funds to institutions to direct aid programs which provide funds to students; and the fact that, as a result of changes in demographics, higher education was no longer a growth industry. With one exception, that of changes in demographics, the trends noted by Glenny in the early 1970's have continued into the present. Current demographic data indicate that there will be future increases in the college age population for some parts of the United States, Abramson (1995).

The area of government regulations has had a significant effect on the condition of facilities. Unfunded mandates such as the Americans with Disabilities Act (ADA), Resource Recovery Act (RCRA), Hazardous Materials Transportation Act (HAZMAT), asbestos, chlorofluorocarbons (CFCs), and others promulgated by The Occupational Health and Safety Administration (OSHA) have redirected facility funds often without administrative input. Some of these unfunded mandates are part of deferred maintenance and others have simply made the deferred maintenance problems worse. The ADA is a civil rights law which allows the university the opportunity to prioritize when and where it will spend its resources. Asbestos can generally be managed through knowledgeable avoidance but future repair and renewal projects are made more expensive because they must address asbestos abatement costs at that time, increasing deferred maintenance. CFCs are affected by several other factors including the cost of the refrigerant, condition of equipment, operating efficiency of the equipment, and overall utility cost structure of the university. As a deferred maintenance cost, CFCs have a tendency to make these costs more immediate rather than higher. Regardless, they contribute to the facility maintenance problems.

Likewise, operating costs to address worker safety and the safety of the campus in general, while extremely important, result in fewer funds available for repair and renewal. Some costs go directly to employees who see them. These include the use of safety harnesses, safety shoes, and periodic training on hazardous materials. Other costs are less direct and often not seen, i.e., administrative costs for documenting compliance (or lack of compliance), purchase of more expensive fuels in order to reach pollution attainment zone requirements, and waste disposal costs. In 1992, Illinois State University, in an attempt to address the HAZMAT rules, proposed a hazardous waste storage facility on campus. Neighbors, fearing chemical exposure from spills or fires, protested. When asked about the chemicals stored in the facility university officials responded with items such as ammonia, acetic acid, and solvents, all in low concentrations. Unfortunately, the university neglected to highlight to the frightened neighbors that these were all chemicals they used in their homes but had to be handled, tracked, and documented in order to comply with the federal laws, requirements that the home owners did not have to meet.

An important source of funds for colleges and universities is the revenue provided by student tuition and fees. At private institutions where the primary mission is undergraduate education, tuition and fees play a significant role in total revenues. These institutions obtain approximately 65 percent of educational and general needs from tuition and fees. For public institutions where the primary mission is undergraduate education, tuition and fees comprise as little as 20 percent of educational and general income. The percentage declines to 17 percent of educational and general income at public institutions which have significant research and/or public service activities (Brinkman, 1990). Because it is a fairly small percentage of total revenue at most institutions, tuition has not had a significant effect on the revenue available to higher education. Fromkin (1990) notes that "...the four fold increase in tuition per FTE student between 1966 and 1984 brought the institution only ten percent more resources per student" (p. 193).

The cost of service delivery required by higher education also has a significant effect on the financial condition of colleges and universities. Professional salaries comprise one of the most significant costs of higher education. Approximately 73 percent of university expenditures are for salaries (Kaiser, 1984) and about 70 percent of a university's operating budget goes to academics (Schaw, 1994). Thus faculty salaries constitute more than 50 percent of the typical university's budget. Faculty are the primary service provider in a university because they are primarily engaged in teaching, research, or public service. Other personnel costs are in support of the faculty. Colleges and universities have often looked to the non-faculty areas first for budget reduction opportunities. When pressed to achieve significant savings professional salaries have been the target because of their significance to the overall budget. This was done through professional salary rates which did not keep pace with inflation (Fromkin, 1990). Halstead (1989) notes the purchasing power of faculty salaries reached its peak in the early 1970's, was at the lowest level in 1981, and has gradually climbed since that time. Halstead (1989) also observes that the present level of faculty salary purchasing power is still below that of 1972-73.

Other costs for higher education have also increased significantly. Inflation affecting the costs of products and services was described as the most serious problem in higher education from the mid-1970's to mid-1980's (Frances, 1984). McPherson, etal (1989) noted that the costs of inputs for colleges and universities, as measured by the Higher Education Price index, rose by 67.2 percent since 1978. By comparison, there was a 58.7 percent increase in the Consumer Price Index and a 72 percent increase in the Construction Cost Index. Halstead states that this differential is a result of not only salary increases by also "increase in the prices of such items as fringe benefit payments and library acquisitions not purchased by the general consumer, plus the larger consumption of utilities" (p. 11). Bernard and Beaven (1985) note that from 1974 to 1985 the cost of utilities in higher education tripled.

Fiscal stress in higher education is not limited to external causes. The effect of fiscal stress has been magnified as a result of the actions of higher education during the boom times of the 1960's and 1970's. During these years of expansion, colleges and universities did an excellent job of spending. Current fund expenditures increased at the same rate as revenues during the late 1950's through the late 1960's. During this time, the average annual increase for both revenues and expenditures was 13.5% (Morgan Guaranty Survey, 1971). "Very little of the money that came into colleges and universities during the lush years was earmarked for a rainy day" (p. 6). Public institutions are often restricted from saving for "a rainy day" and are less well prepared to handle financial setbacks.

Changes in governmental funding for higher education facility construction has also had an effect on college and university financial conditions. Federal programs provided a high of $1.1 billion for facilities and equipment in 1967. By 1978, this funding had fallen to $144 million, an 87 percent reduction excluding inflation, (Kaiser 1984). Likewise, federal support for facility operations, as part of research and development grants, peaked in 1965 at $126 million and dipped to $22 million (constant dollars) in 1981 (p. 13); similar funding changes resulted in state support.

The cost of maintaining and operating the facilities constructed in the "fat" times fell on universities and in some cases on the students through tuition increases.

Institutions respond to adverse financial conditions in a variety of ways. One set of responses includes those actions designed to resist the change (Mingle and Norris, 1981). In general, these responses focus on increasing revenues. Increases in either enrollment or tuition are two methods that institutions may use to change their level of income. Public institutions seek additional support through increased funding from the state government. However, given the current status of most state economies, this option is limited, if not non-existent. Another strategy of resistance is to diversify revenue sources. This provides the institution with increased flexibility to deal with the changing financial conditions (Brinkman, 1990). Diverse revenue sources include research funds from public and private organizations, lease-back schemes on existing facilities, royalties for intellectual property developed at the university, and privatization or contracting of some in-house services at lower cost.

In the early years of collegiate fiscal stress, Kaiser (1976) provided several techniques to manage facilities with declining resources. 1) Physical Planning Policy, done in coordination with university fund-raisers, reduced the growth goals of the university, identified marginal or minor facilities to divest, and feature facilities for which to raise capital campaign funds to address deferred maintenance needs. 2) Evaluation of the university's deferred maintenance, coordinated with #1 above, with a concentration on protecting facility exteriors then addressing the unseen building systems. 3) Increased space utilization through space studies and the identification of facilities which would provide higher assignable to gross efficiencies if renovated.

This effort included consolidation of activities in different buildings into a single structure and the abandonment of an old, high maintenance cost facility. 4) Controlled maintenance program, where tighter controls on maintenance work were instituted as well as improved coordination in employee training and documentation of work performed. These functions are typically done by a computerized maintenance management system (CMMS) now, but not all universities have instituted such systems nor are the ones using such systems taking full advantage of the potential power. And 5) use of energy conservation projects to free limited utility funds to address other campus priorities or future maintenance projects which have energy paybacks.

Each of the five techniques continues to be a reasonable strategy to manage within fiscal constraints. However, in many cases energy conservation projects were really cost avoidance efforts, rather than savings due to the high rate at which utility costs were growing in the mid to late seventies. Likewise experience tells us now that the reduction of outside air for heating/cooling savings has become a deferred maintenance problem of its own with the issue of indoor air quality (IAQ) and sick building syndrome (SBS), the facility issues of the 90's. If operating budgets have been adjusted for energy cost increases and modern methods are employed for energy conservation, there remain significant savings available for colleges and universities. These savings can be used to address deferred maintenance issues as well as meeting operational cost challenges.

The second reduction strategy identified by Kaiser has been widely employed by colleges and universities is to reduce expenditures for the physical plant. Campbell (1982) found that many institutions were "deferring maintenance of buildings and equipment, and postponing needed equipment purchases" (p. 11). He noted that reductions in plant expenditures were intended to alleviate immediate financial problems. However, this practice was now itself a factor in the creation of additional financial stress. In a test to determine the effect of deferred maintenance on institutional financial condition, Jenny, etal (1982) included a modest charge for capital renewal and replacement (1.5% of replacement value) in the annual financial reports of a sample of 121 institutions. Including this cost doubled the number of institutions with deficits. The number of institutions which would have operated at a deficit increased from 48 to 96 in 1977, 41 to 98 in 1978, and 37 to 87 in 1979. Thus the increase in deferred maintenance is an essential and successful method to reduce short-term deficits while increasing long-term liabilities. However, when no accounting is made for the cost of facility use, either through depreciation or other means, universities develop a false sense of financial health which can become an unchecked cancerous growth.

This was highlighted by Walter A. Schaw, former executive vice president of APPA, in an article describing Arkansas's higher education funding needs (Leotta, 1994).

> "Funding for facilities operations has sustained successive reductions in many states during the recent recession. The condition of deferred maintenance has worsened at some states as preventive maintenance has been reduced and funding to reduce backlogs has been required for other purposes. The low priority of the problem in a recent APPA opinion poll may indicate that some facilities officers may have given up on making real progress until better times materialize."

The inability of facility officers to continuously articulate the facility maintenance needs, in a reasonable way assures the defeatist attitude identified above and assures rapid disintegration of facilities.

2.5 Deferred Maintenance

One of the symptoms of rapid plant growth and declining financial health has been the accumulation of renewal and rehabilitation projects as well as maintenance activities which are not completed, postponed, or never begun as a result of a lack of funds. The term most frequently used to describe this accumulation is "deferred maintenance." This term was initially associated with the funding of an item or project whose life span exceeded the annual or biennial budget of an institution, but which was too short to meet the requirements of the traditional capital budgeting process. Increasingly however, deferred maintenance has come to be associated with maintenance delayed as a result of budget constraints (California Postsecondary Education Commission, 1983). Kaiser defines deferred maintenance as, "maintenance work deferred to a future budget cycle or postponed until funds are available." This includes (following NACUBO/APPA 1982 terminology): postponed renewal and replacement projects which "extend the life and usable condition of campus facilities and systems", undone alteration and renovation projects which are products of "a change in the use of the facility or a change in program", delayed or ignored normal maintenance such as housekeeping, preventive maintenance, routine inspections, and call-in requests, as well as unperformed unscheduled major maintenance (sometimes a disaster which results in a massive closure of buildings). The accumulation of deferred maintenance in colleges and universities, and the financial liability this represents, directly affect the ability of these institutions to meet the immediate and long term funding requirements of their existing physical plant.

The magnitude of the deferred maintenance problem has been described in a variety of ways. One method has been to determine the total amount or percentage of space in which maintenance has been deferred. In 1974, a survey by the National Center for Educational Statistics (NCES) reported that 20 percent of all campus facilities were in unsatisfactory condition (Kaiser, 1989). In the early 1980's, several states surveyed their higher education facilities and reported conditions comparable to those in the 1974 NCES study. Approximately 20 percent of all space in the participating states was found to be in poor condition. A survey of building condition (Halpern 1987) found that approximately "one-half of all facilities will require major renovations during the next 20-25 years because of age" (p. 2). More recently (Kaiser & Davis, 1996) measured deferred maintenance changes since 1988 and found that it increased in all types of colleges and universities except private 4-year and masters institutions.

Another method to estimate the magnitude of the deferred maintenance problem has been to determine the total cost of deferred maintenance. Jenny, etal (1980) estimated the total amount of deferred maintenance in higher education to be between $756 million and $2.1 billion. Kaiser (1984) estimated that total dollar amount of deferred maintenance and capital renewal at $30 billion. His estimate was based on a method which used building condition codes and estimated replacement cost of physical plant. Using revised space and cost data to update Kaiser's research, Rush and Johnson estimated in 1989 that colleges and universities had a CRDM backlog of $60 to $70 billion. Of that amount, approximately one-third was considered "critical" (requiring resolution and elimination within three years) Table 2.1 provides various estimates of deferred maintenance. In 1996 (Kaiser & Davis) estimated accumulated deferred maintenance (ADM) to be $26 billion not including capital renewal needs with $7.125 billion needs labeled as urgent.

TABLE 2.1

ESTIMATES OF DEFERRED MAINTENANCE
(DOLLARS IN MILLIONS)

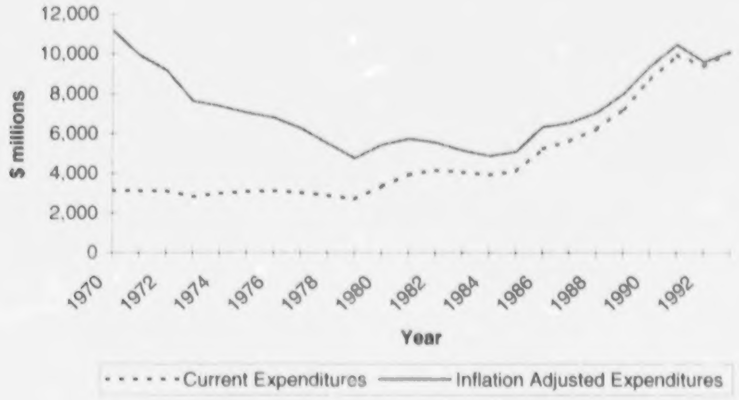
Year	Scope of Survey	% of Sq. Ft. Found to be Unsatisfactory	Estimated Cost of Renovation/Renewal (dollars in millions)
1974	National	20	Not Determined
1980	National	Not Determined	$756-2,100
1982	National	Not Determined	$35,000
1982	New York	20	Not Determined
1982	North Carolina	17	$302
1982	Texas	Not Determined	$301
1983	California	Not Determined	$2,000
1983	Indiana	24	$3,340
1984	Columbia University	Not Determined	$247
1985	Maryland	Not Determined	$224
1995	National	Not Determined	$26,000

Source: Robert T. Forrester, A Handbook on Debt Management for Colleges and Universities, NACUBO, 1988 and Kaiser & Davis, A Foundation to Uphold, APPA, 1996.

The accumulation of deferred maintenance can be traced to two factors: (1) the declining level of capital investment in, or additions to, existing plant and (2) the level of funding for annual operations and maintenance. Kaiser (1989) states "the amounts spent on plant additions represent capitalized investments to replace obsolete facilities, meet new program requirements, and enhance the quality of campus life" (p. 3). Rush and Johnson (1989) point out that some institutions may choose to meet renovation needs through new construction. However, this does not eliminate the need to renovate existing facilities. They note that because institutions seldom demolish older buildings, "...in all likelihood the more new construction a college undertakes the more renovation is needed" (p. 42). If this is in fact the case, then institutions with large amounts of new construction will continue to have substantial renovation requirements within their existing physical plants. An example is the vacation of one department from an existing building to a new facility followed by the immediate expansion of another department into the vacated space without complete resolution of all deferred maintenance therein. As Figure 2.5 indicates, actual expenditures for additions to the existing physical plant in higher education were relatively constant until 1985 then increased at a rate of almost $750 million per year. When these expenditures are adjusted for inflation constant dollar expenditures for additions to existing plant declined by almost fifty percent between 1970 and 1985 and then reversed so that by 1993 expenditures were almost at the same level as in 1970.

FIGURE 2.5

ADDITIONS TO PHYSICAL PLANT VALUE
INSTITUTIONS OF HIGHER EDUCATION



Source: Digest of Educational Statistics, 1995. p.358.

The second major factor in the accumulation of deferred maintenance is the level of funding provided for annual operations and maintenance expenditures. Kaiser (1989) states that, "How much is expended on operations and maintenance has a direct effect on the condition of campus facilities" (p. 3). Table 2.2 indicates the percentage of education and general expenditures for plant operations from 1970 and 1993.

TABLE 2.2

EXPENDITURES FOR PLANT OPERATIONS AND MAINTENANCE HIGHER EDUCATION INSTITUTIONS 1970-1993

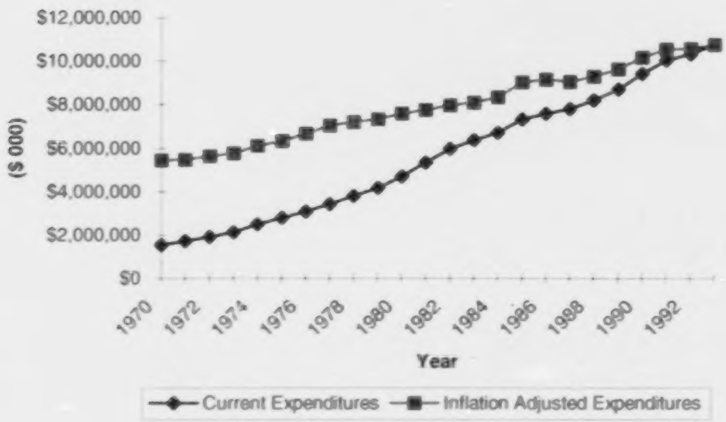
Year	Total Expenditures (000's)	Percentage of Budget
1970	$1,541,698	7.3
1971	$1,730,664	7.4
1972	$1,927,553	7.5
1973	$2,141,162	7.7
1974	$2,494,057	8.1
1975	$2,786,768	7.9
1976	$3,082,959	7.9
1977	$3,436,705	8.1
1978	$3,795,043	8.3
1979	$4,178,574	8.2
1980	$4,700,070	8.3
1981	$5,350,310	8.4
1982	$5,979,281	8.5
1983	$6,391,596	8.4
1984	$6,729,825	8.2
1985	$7,345,482	8.2
1986	$7,605,226	7.8
1987	$7,819,032	7.4
1988	$8,230,986	7.2
1989	$8,739,895	7.1
1990	$9,458,262	7.0
1991	$10,062,581	6.9
1992	$10,346,580	6.6
1993	$10,783,727	6.5

Source: Digest of Educational Statistics, 1995, p. 346.

Adjusting these expenditures for inflation by the Construction Cost Index indicates that operations and maintenance expenditures have increased slightly over time. However, as Figure 2.6 indicates, the constant dollar increase has been much less than the increase in current dollars resulting in a net loss.

FIGURE 2.6

HIGHER EDUCATION
OPERATIONS AND MAINTENANCE EXPENDITURES



Source: Digest of Educational Statistics, 1995, p. 346

The indication of these data is that plant operation expenditures have increased slightly in real terms, yet Kaiser (1989) states that there are several reasons to expect significant increases in operations and maintenance expenditures in the future. First, increased enrollments will result in increased facility use. A 1994 survey by the U.S. Department of Education indicates that school-age student populations (5 to 17 year olds) are expected to increase by 19% between 1990 and 2005(NCES, 1995). It is assumed that these students will be attending colleges or universities in similar proportions as in the recent past and will result in corresponding demands for higher education facilities. Second, buildings now employ more sophisticated technology and require increased levels of maintenance. "As new space is constructed or existing areas are remodeled to include more sophisticated equipment, the cost of operating the physical plant increases." (Illinois Board of Education, 1991) Third, the costs for utilities, personnel, services, and material have increased at rates higher than inflation.

Given these factors, it is clear that operations and maintenance activities must be maintained at increasing levels and that minor increases in expenditures will not suffice. As a result, financing deferred maintenance will continue to be an issue within American higher education as an economical means to provide the necessary infrastructure for instruction.

2.6 Depreciation

Depreciation accounting is widely used in for-profit organizations as a means of acknowledging the consumption of capital assets in business operations. Under this concept, the value of tangible or capital assets consumed each year is considered an annual operating expense. The operating expense thus being a cost of doing business reduces net income and taxes on that income. Kraal (1992) provides a good summary of the history of depreciation rules for not-for-profit institutions. This accounting technique is not widely employed in not-for-profit institutions and is not applied at all for government supported institutions. This is due to two issues: appropriateness of the procedure in not-for-profit organizations and the effectiveness of the practice as a measure of renovation and renewal costs, Cooper (1984).

In two Accounting Research Bulletins (ARB) in 1953 and 1954 depreciation accounting is defined as "a process of allocation and not of valuation which should attempt to distribute the cost, less salvage value, of a tangible assets over its estimated useful life in a systematic and rational manner". The bulletins did not apply to nonprofit organizations. The Financial Accounting Standards Board (FASB) has gradually incorporated financial accounting and reporting practices for nonprofit organizations into its guidelines and procedures. The development of depreciation guidelines has culminated in the adoption of FASB Statement of Financial Accounting Standards no. 93, Recognition of Depreciation by Not-for-Profit Organizations (1987). This statement requires all not-for-profit organizations to recognize depreciation on their long-lived capital assets beginning January 1, 1990. However, there is no comparable statement from GASB, Governmental Accounting Standards Board, to which public colleges and universities must typically adhere. Public colleges and universities have been specifically exempted from FASB no. 93. NACUBO, the National Association of College and University Business Officers, has resisted the use of FASB no. 93 out of concerns for consistency between private and public institutions and their associated hospitals.

Regardless, it is still useful to examine the basis for the FASB decision to require the application of this accounting principle to not-for-profit institutions. Three basic approaches identified by Collins and Forrester (1988) are used to justify the need for depreciation:

> 1. depreciation is an allocation of cost and there is a need to match expenses with net income;
> 2. depreciation is a means, however indirect, of providing for the replacement of assets; and
> 3. recognition of depreciation is necessary for an organization to obtain an accurate measurement of the reduction of capital (net assets) and to ultimately reach the goal of overall capital maintenance. (p. 23-24).

Collins and Forrester (1988) note that of these three approaches the one on which FASB placed the most weight was the issue of capital maintenance. FASB recognized that it is still important to recognize the relationship between inflows and outflows of resources. This includes the impact of organizational activities on net or capital assets. They cite FASB as follows:

> Unless a not-for-profit organization maintains its net assets, its ability to continue to provide services dwindles ... The organization's net assets decrease as it uses up an asset unless its revenues and gains at least equal its expenses and losses during the period (depreciations) ... Depreciation is an essential part of measuring the costs of services provided during a period. Omitting depreciation produces results that do not reflect all costs of services provided. (p. 26-27).

Two reasons are used to argue against the use of depreciation in not-for-profit organizations. First, many not-for-profit organizations fund capital items through gifts or grants, including an expense for depreciation in an annual financial statement would not be appropriate. Second, depreciation is used by for-profit organizations as a method to determine operating expenses for tax purposes, and thus does not fulfill the same need. Recent changes by local governments in the way they treat auxiliary enterprises of colleges and universities may assist in speeding a change by not-for-profit institutions into the use of depreciation. Recognition that older facilities are less useful for the high tech needs of university instruction may provide additional justification.

The effectiveness of depreciation as a method of estimating the renovation and renewal costs of the higher education physical plant was addressed by Kraal (1992) and was shown to perform reasonably well in the long term but was unable to accurately predict the funding level required year by year. In early years typical depreciation methods overstated funding needs while in later years, as major equipment reached the end of its predicted life, depreciation methods understated needs. Kraal (1992) noted that straight line depreciation performed well for buildings below 15 years of age but it "was not a realistic estimate of the renovation and renewal costs for a building inventory that consisted of buildings older than 15 years of age (p. 179)."

Kraal noted the typical depreciable life of a building was 50 years. He also recognized that colleges and universities utilize buildings for more than that life. Resetting of a depreciation cycle following major renovation over-predicted the funding needs of an older building. This likely resulted from predictable lives of structural components exceeding a 50-year life. Other major maintenance cost predicting methods, discussed below, address the longevity of foundations and structural systems of buildings by utilizing factors which recognize the portion of the building cost belonging to these components. As a result, these other methods have lower predicted expenditures in early years compared to depreciation methods.

Other methods to predict major maintenance costs may be more appropriate, since colleges and universities typically remain in the same location for more than 50 years, and alumni are often nostalgic about older buildings when returning to the campus (Kaiser, 1984). This last statement is attributed to the fact that when an alumnus returns to the University for a 50-year reunion the remembered faculty are no longer at the university but the buildings remain (Kaiser, 1989). Kaiser argues that reunions offer important opportunities for fund raisers to address the university's financial needs. Higher education facilities officers are challenged by this situation and benefit from these opportunities when they have the ability to make the connection between the condition of buildings and donor generosity.

2.7 Formula Funding

One of the most important and highly used funding mechanisms within higher education is the process of formula budgeting (Brinkman, 1984). Although the extent of formula use varies from year to year, formulas are used in approximately one-half of the states (Meisinger, 1976; Brinkman, 1984). Meisinger (1976) defines formulas as "... a decision rule of unspecified complexity and domain 'imposed' on institutions of higher education by state agencies and used as an aid to calculation for generating and reviewing institutional budget requests or parts thereof" (p. 5). Formulas used in the budgeting process are mathematical statements linking appropriations to institutional characteristics. Meisinger (1976) identifies two quantitative aspects of a formula, variables which provide the basis for the formula and rate schedules which determine the level of funding.

There are several ways to perceive formulas in the higher education budgeting process. One perspective views them as an objective means for implementing subjective judgments. A second view identifies formulas as standards formed resulting from resource allocation policy judgments. A third perspective sees formulas as forming the central part of a bureaucratic decision-making process and, once established, they "routinize and, to some extent, depoliticize the decision process" (Brinkman, 1984, p. 26). In many cases where the formulas have not changed over time, by eliminating the subjectivity, judgment, or politics, the formulas become a governing model which drives other decisions rather than resulting in funding.

Meisinger (1976) describes formulas as fulfilling a number of roles in the budgeting process. They provide assumptions about how colleges and universities function and descriptions of their organizational behavior. Formulas also establish priorities by establishing a value for various institutional characteristics. A formula serves as "a type of organizational memory; it is an accumulation of past decisions, commitments, and agreements" (p. 6). Similar to the role of "memory" is the role of contract. In return for agreeing to the formula process, participants in the process expect to receive the funding generated by the formula.

Once implemented, formulas perform four functions within the budgeting process (Meisinger, 1974). One of the most important functions is to reduce the uncertainty inherent in the appropriations process. For the funding agency, formulas put some limit on the amount of funds which will be provided. The requesting institutions are also provided with a basis level of support. A second function of formulas is to enhance the process of "accommodation among organizations" (p. 8). By introducing an open process of resource allocation, competition among institutions is reduced. A third function of formulas is to provide some boundaries to negotiations on the level of budget increases or decreases. The fourth function of formulas is to encourage the "convergence of expectations on approximately how much each institution should receive" (p. 9).

Sherman and Dergis (1984) proposed a formula which is based on building age, hereinafter referred to as the Age Method. Their formula calculates estimates of renovation and renewal costs using a building age ratio. This ratio is the actual age of the building divided by the sum of the digits contained in the building life span. This method creates a formula in which older buildings require more renewal funds than newer buildings. Sherman and Dergis (1984) state that "... in general, building renewal needs grow with the average age of the group" (p. 6). This approach assumes a 50-year life span for buildings, producing a building age sum of 1275 $(1+2+3+\ldots+49+50 = 1275)$. This formula also assumes that the cost of building renewal will be less than that of a new building. Sherman and Dergis also use two thirds as the maximum renewal cost of the building. The estimated annual cost of renovation and renewal is the product of the age ratio multiplied by the percentage of building replacement value.

$$RE = (BA / 1275) * (0.67 * BV)$$

where: RE is the renovation/renewal expenditures required
BA is the building age
BV is the building replacement value

Sherman and Dergis (1984) also state that building age should be adjusted to reflect previous renovation activities. The building age adjustment involves calculating a building age reduction ratio. This ratio is derived from renovation expenditures and maximum building value at the time of the renovation. The ratio, or ratios if there has been more than one renovation, is summed and used to reduce the actual building age. The annual appropriation is then calculated by using the adjusted building age instead of actual age in the original equation.

There is a threshold of renovation expenditure which must be exceeded before one makes a building age adjustment. "In order to qualify as building renewal, a project had to cost at least 10% of the" current replacement value of the facility (Sherman & Dergis, 1984). The goal of this threshold was to eliminate most cosmetic and minor maintenance projects and to identify only those which had a clear influence on the useful life of a building. They also make note of adjustments to the formula or its application when significant work is done to a portion of the building but the overall building size or replacement value limits consideration of the renovation because the threshold is not crossed. In this latter case, judgment becomes a key factor in the application of data to the formula and the elimination of subjectivity or judgment is not accomplished. If however, this method is utilized, once the subjective decision is made, the formula is adjusted annually and the method returns to its non-political form.

2.8 Capital Renewal Funding Formulas

Formulas are used in a variety of areas outside the budgeting process. A survey done for a California Postsecondary Education Commission found that 20 states rely heavily on the use of formulas in the area of space standards and guidelines (MGT Consultants, 1989). In the state of Texas, Kraal (1992), formulas are used to determine the level of space utilization within institutions and to project future space needs. However, Texas does not have a formula which addresses the need for major repair and renovation, the need for conversion of space to other uses, or the need for energy conservation modifications. In Illinois, formulas are used to determine the level of funding a university is supposed to allocate for renovation, repair, and space conversion. In its 1986 annual recommendation to the legislature for operating and capital funds for the public universities the Illinois Board of Higher Education (IBHE) stated that "O&M costs do not vary significantly with enrollment increases or decreases, comparison among campuses of per credit hour physical plant costs are not very meaningful". Thus the Illinois formula is based on square footage of campus buildings, building type and fundamentally on the estimated replacement value of the buildings. This formula method is hereinafter referred to as the Facility Funding Formula.

A variety of methods have been proposed to determine renovation renewal needs for higher education physical plant. Callhan and Collins (1986) describe three general methods of determining capital renewal requirements. One method bases funding levels on a percentage of the annual budget. This approach is simple to understand and apply. The level of appropriation depends on the size of the budget or the percentage of budget used. This approach does not account for the aging factor associated with buildings nor does it account for the physical size of the facilities. Indeed, it requires that all campuses using the formula are essentially the same in academic mission, goals, physical make-up, distribution of space types, and staffing. A second general approach uses an audit or evaluation of plant condition to determine funding requirements. This method has a high cost of implementation and does not provide data which can be used for projecting long range estimates. It is useful to assess how well other methods have worked when applied appropriately. The third approach includes those methods which attempt to quantify capital renewal requirements through some type of formula. Formulas, because of their reliance on historical data, may extend past inadequacies in funding into the future. However, as Callhan and Collins (1986) note, the increasing sophistication in the development and use of formula approaches makes some of these methods very viable techniques for determining and allocating capital renewal funds. But sophisticated formulas and techniques have a high cost for maintenance and data gathering in a dynamic environment. A fourth method has been proposed by Neely & Neathammer (1991) for military facilities based on a survey of historical costs. This method is composed of two general factors, annual repair and maintenance costs and major repair and high cost tasks. This method will be investigated in detail later in this study.

A number of methods which fit into the formula approach have been proposed as means for estimating renovation and renewal costs. Bareither (1982), citing a void in the funding process for renewal and replacement of building components, proposed a formula to provide the funds required for annual and long-term subsystem replacement. He stated that the "essential elements are the calculation of the replacement cost and the number of times the components of the building undergo change" (p. 18). In Bareither's formula, it is assumed that a building will last 100 years and will undergo two complete renovations. Based on an analysis of building components, Bareither assumes also that approximately one-third of the building will never require renovation. This is a reflection of the portions of the building with much greater longevity than other portions; i.e., a well designed and constructed foundation and superstructure will have a life far in excess of 50 years. The result is an equation which calculates annual renewal and replacement costs as follows

$$AR = (RC * 2/3) / 100$$

where: AR is the annual renewal and replacement cost
RC is the estimated current replacement cost of the facility

Bareither states that the "one time per 100 years" value means that funds equal to the sum of annual costs for 100 years should be set aside or developed to meet the requirements of major remodeling. Due to the simplicity of the formula it must also assume a reasonably smooth distribution of facility types and ages, otherwise idiosyncrasies are not sufficiently accounted for and shortfalls or excesses will result. A variation of this formula is used by the Illinois Board of Higher Education in annual reports from the twelve public universities. The formula has been modified so that the individual universities are obligated to provide 1/2 of the annual renewal and replacement funds from their individual operating budgets, the state is assumed to provide the balance. Since no funds change hands based on this formula it is of little value to either party. In addition, there is no obligation on the part of the individual universities to demonstrate that they have followed the guidelines of the formula so that the annual determination of the funding levels based on the formula are a mechanical exercise.

Another formula approach has been to estimate renovation and renewal costs using the life cycle of key building components. Kaiser (1984) proposed a formula which develops a cost index for individual buildings. This index is based on individual building systems, the cost of each system as a percentage of total replacement cost, and the average life cycle of each building subsystem. These data are then used to calculate a total repair and replacement index for each building. This index is then multiplied by the building replacement value to determine the level of annual funding required for renovation and replacement.

Biedenweg and Hutson (1984) have proposed a model similar to that developed by Kaiser (1984) to determine the future renovation and renewal costs for Stanford University. They state that there are "actuarially predictable cycles for facility renewal and replacement (i.e., the components or subsystems of a facility, ... have identifiable life expectancies and will require replacement after predictable periods of time)" and that "these cycles will continue to repeat themselves as long as the facility continues to serve its intended function" (Biedenweg and Hutson, p. 11). In their formula, estimates of renovation and renewal costs are a function of (1) date of building construction, (2) building type, (3) subsystem life span, and (4) subsystem cost. In this approach date of construction is the starting point which establishes subsystem life cycles and the date at which the replacement of these subsystems occurs. The model calculates future costs by determining the cost of an individual subsystem replacement and the year in which this replacement will occur. These values are placed in a table which allows costs to be summed by year. The table and calculations may be extended indefinitely. This method will hereinafter be referred to as the BRCI Model derived form the Biedenweg & Hudson paper in 1984 titled "Before the Roof Caves In".

The building subsystem approach is also used by Dunn (1989) as a part of a total facilities management model which addresses the need to eliminate deferred maintenance, fund necessary adaptation of facilities. An audit is used to evaluate existing plant condition and determine the cost of eliminating deferred maintenance. He suggests that estimates of facility adaptation costs be based on a projection of the average annual expenditure for these activities over the past five years. Renewal and replacement costs are estimated using a modification of the subsystem approach developed by Biedenweg and Hutson (1984). Dunn proposes that the current replacement cost for each subsystem be divided by its estimated life span to provide an annual renewal cost. These costs are then summed to provide a renewal cost for individual buildings.

2.9 Empirical Methods

Empirical methods of determining annual deferred maintenance expenditures are based on a facilities audit or study of building expenditures over time. A widely used method to determine the cost of renovation and renewal for higher education facilities is based on a building condition audit. This process is employed by the North Carolina State Commission on Higher Education Facilities. It "estimates the cost of bringing all campus buildings to a satisfactory condition by renovating unsatisfactory facilities and replacing buildings designated for demolition" (Facilities and Utilization Study 1987, p. 161). This method involves multiplying the estimated replacement value of individual buildings in unsatisfactory condition by an appropriate "cost midpoint based on the condition of the building" (p. 161). This method was used by Eastern Illinois University in 1987 and applies a similar building condition factor and multiplies it by the estimated replacement cost of the facility.

Kaiser (1982, 1993) developed a facilities audit work book for college and university physical plant administrators to assess, in a logical and consistent manner, the condition of campus facilities and to assign a cost to deficiencies. While physical plant administrators had been performing audits for many years, the lack of an industry-wide model likely inhibited acceptance of the data. Brenda N. Albright, deputy executive director of the Tennessee Higher Education Commission said "A good audit is essential for future planning. It reveals what needs to be done." She argued that the audit formed the foundation to a series of steps, including a plan for renewal, which are used to allot funds fairly. The allocation can be done between universities in a system, or state, or applied internally against other benchmark information. A similar empirical method was developed by Bareither (1981). In

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Bareither's method a building is examined in 7 areas to develop a facility condition index. Limitations in deficiencies were inserted to keep each area within a proscribed percentage of total building value.

An empirical method based on several building factors, including components, was developed by Neely & Neathammer using Army facilities as the model. Their system examined building components down to the material and functional characteristics. For instance, there exist differences between brick or stone for exterior wall construction and therefore there are differences in annual maintenance costs as well as major maintenance and replacement costs. Similarly, the system identifies differences in the life of these components. Some material types may have a life of 10 years and others more than 50 years. These characteristics are similar to models of Biedenweg & Hutson, Kaiser, and Dunn. However, Neely & Neathammer provide considerably more detail and correspondingly require more detail of facility components. The application of Neely & Neathammer's system is applicable to life-cycle cost studies and value engineering building designs. The system has been adopted by ASTM for life-cycle cost analysis and appears in a standard document it publishes.

Neely & Neathammer developed several models to apply the results of their research. The simplest model is based on square footage. The models become more complicated as they include more factors. The subsequent models include: building use, building age, and finally building components and materials. The army facilities examined were very diverse and included both civilian and military components. Offices, housing, maintenance, production, meeting, recreational, and educational facilities were all included. As a result, they assert their models can be applied to cities, universities, and corporations for resource predictions. Because of the broad range of data needs these models range from very easy to very difficult to implement. But, because of the breadth of the study and acceptance of these models by ASTM, other organizations, and information providers, there is a great deal of credibility associated with the models. This model will be hereinafter referred to as the USA-CERL Model.

2.10 Conclusion

This study examined five different approaches to determining the renovation and renewal needs for the existing higher education physical plant. The first were depreciation techniques and models used by for-profit organizations and now being advocated for non-profit organizations. This model has been resisted for governmental accounting and uniformity reasons but could be applied as a technique to determine university budgets. Formula funding methods are used not just for facility maintenance reasons but as an organized, bureaucratic, means of allocating funds based on independent characteristics. These methods vary widely and are subject to the changes in data which may not reasonably reflect individual differences in facility design, make-up, or usage. Formula funding is applied in three forms: by building age factors, by space utilization and replacement cost factors, and by building component life-cycle and cost factors. Finally, a method which utilizes empirical information gathered from a survey of building conditions is combined with replacement costs to determine the backlog of maintenance needs and allow for individual development of budgets to eliminate the backlog.

These methods have been selected because they provide a representative sample of formal approaches. They utilize different types and levels of input data which may be familiar to a variety of people and they allow for comparison of efficacy through ability to predict maintenance needs for different facilities.

This chapter provided a review of the issues relevant to this study. It began with an examination of the historical growth and development of the higher education physical plant. Approximately two-thirds of the buildings used by higher education today were constructed during the 1950's and 1960's. The current size, more than 4 billion square feet, and value, estimated at greater than $500 billion, make the physical plant a significant asset for colleges and universities, one which will continue to increase in importance.

The chapter also examined the sources of fiscal stress in higher education as well as various institutional responses to the changing financial environment. One institutional response to fiscal stress has a direct impact on the physical plant. This response is the practice of deferring funds necessary for both the annual maintenance needs and long range renovation and renewal requirements of existing building. While initially intended to reduce the impact of fiscal stress, this practice is now viewed as creating additional fiscal difficulties for colleges and universities.

The chapter concluded with a review of the basis budgeting techniques for facility renewal funding in higher education. This review examined some of the various funding formulas used to estimate renovation and renewal costs. The history and development of these techniques was discussed. Shortcomings of each of these overall techniques were discussed as well as their appropriateness either for facilities maintenance or the budgeting process.

If colleges and universities are to continue to grow and meet the demands of the future, existing facilities must be maintained. This is particularly true of technology based programs requiring the use of sophisticated equipment and facilities. The challenge for the presidents and governing boards of colleges and universities is to find the funds necessary to accomplish this task in an era of declining financial support for higher education activities. One way to estimate the level of future needs is to predict funding requirements by several approaches. The following chapter outlines the history of a specific university, its funding levels, constructed facilities and further discusses methods which could be used to address its deferred maintenance needs.

CHAPTER 3

METHOD OF PROCEDURE

3.1 Introduction

This chapter describes the methodology employed to answer the research questions posed in Chapter 1. Included in this chapter is (1) a description of the sample used in the study, (2) a description of the data and variables necessary to apply the models and an explanation of how this information was acquired, (3) a description of the models used in this study, (4) a description of the mathematical techniques used to develop simple equations for predicting funding needs based on the US Army CERL study, and (5) the plan for analyzing the results produced by the study.

3.2 Sample Selected

Building inventory data from Eastern Illinois University, Charleston, Illinois, were used in this study. This inventory was selected because it was readily available to the researcher, contained the data elements required by the models examined in this study, and included a number of buildings with different characteristics. In fiscal year 1995 the university had 11,424 students, 1,696 faculty and staff (excluding student workers) and had a total annual educational and general budget of $64.38 million and an auxiliary enterprise budget of $42.66 million. The Eastern Illinois University (EIU) campus consists of 99 structures including major additions, comprising 3 million gross square feet. The state supported building inventory, non-residential and other non-auxiliary facilities, consists of 42 buildings totaling 1,340,695 gross square feet. Estimated replacement value of the state-supported buildings is $253,954,514. The book value of these is $37,536,340. These estimates exclude campus horizontal infrastructure (roads, sidewalks, steam and electric distribution, other utilities, and landscaping) which are common to all facilities.

The campus grew significantly between 1957 and 1973 with the construction of over 2.2 million gross square feet of both academic and auxiliary facilities; a 650% increase in space. During that time, virtually no renovation of existing facilities occurred. Almost all capital construction consisted of new buildings and additions. This large increase in space was required to accommodate the student body which grew from 2,186 full-time student enrollment (FTSE) to 8,307 in 1972. In the 1960's the university followed a growth policy which resulted in a population growth rate of about 10 percent each year (Tingley, 1974). Since the early 1970's an additional 300,000 gsf of space has been constructed and 120,000 gsf of space purchased.

Some of the earlier buildings in the 1957 to 1973 time frame were constructed through a state-wide sale of bonds for higher education. The Universities Bond Issue of 1959 provided $195 million at the six state supported institutions of higher learning (Tingley, 1974). Of this overall amount, Eastern Illinois University received $8,325,961. These funds were used to construct six buildings comprising 346,734 gross square feet. The buildings ranged in complexity from maintenance facilities for the campus to academic and research science facilities.

In 1995 the average age of campus buildings is 38 years old. All buildings have an anticipated 50-year life. From this overall statistic, six buildings are more than 50 years old and have received limited renovation to extend their useful life. The average age of buildings constructed during the major growth period (1957 - 1972), comprising two-thirds of the campus, is 30 years. This coincides with concerns expressed by Albright (1982) over average building age and future renovation needs.

Likewise, tight financial conditions have limited the amount of funds available for daily as well as major maintenance efforts to preserve the buildings. Recent efforts by the facilities officers for the state-supported universities of Illinois and their respective administrations have proved successful at increasing the funds available for deferred maintenance efforts, however daily maintenance funding requirements remain far short of actual need and further exacerbate the deferred maintenance problems. Techniques to document and justify the maintenance needs as well as demonstrate their efficient and effective use may be a more important exercise.

Although the total EIU campus building inventory contains nearly 100 buildings, the data required for this work is centered around 24 state constructed/owned facilities. This subset of buildings was selected as the primary sample for this study. The group of buildings in the sample comprise approximately 87 percent of the total replacement value and 89 percent of space of the state-supported building inventory. Auxiliary enterprise facilities were excluded from the study because less data was readily available and because it was supported from a different funding source. A listing of the buildings in the sample appears in Table 3.1. The data is organized by building number which corresponds to the approximate construction sequence. There is some duplication of building numbers due to additions to buildings. Gaps in the building number sequence is a result of auxiliary facilities included in the numbering system but not included in this study.

TABLE 3.1

LIST OF BUILDINGS IN STUDY

Building	Building No.	Constructed	Original Cost
Old Main	1	1896	$200,000
Blair Hall	3	1911	$75,000
Student Services	5	1927	$218,000
McAfee Gymnasium	7	1937	$458,348
Physical Science	8	1938	$326,125
Physical Science Addition	8	1972	$3,340,000
Booth Library	10	1950	$2,010,000
Booth Library Addition	10	1968	$2,171,000
Buzzard Building	19	1957	$2,000,000
Fine Arts Center	23	1958	$1,250,000
Fine Arts Addition	23	1973	$1,941,542
Life Science	29	1961	$1,195,393
Life Science Annex	29	1961	$435,948
Clinical Services	35	1964	$465,500
Coleman Hall	36	1965	$1,091,058
Coleman Addition	36	1969	$1,825,000
Physical Plant	37	1965	$225,415
Central Stores	54	1973	$459,125
Lantz Gymnasium	40	1966	$2,860,000
Lantz Phase 2	40	1966	$825,00
Lantz Phase 3	40	1971	$386,447
Klehm Hall	42	1967	$1,915,288
Klehm Addition	42	1969	$646,500
Lumpkin Hall	71	1991	$6,361,100

There are two independent variables presented in Table 3.1 which are useful in developing funding needs in several of the models examined here. Building construction date and construction cost can both be used in the depreciation and formula funding models. As will be explained later, building age may also be used to determine inflationary adjustments for construction in order to estimate the current replacement value of the building, also useful in the two models.

3.3 Description of Variables and Data Collection

This section provides a description of the variables required by the models examined in this study, as well as how these data were acquired.

3.3.1 Description of General Independent Variables

Each of the five general methods described in Chapter 2 utilize different combinations of data to arrive at a prediction for deferred maintenance funding needs. The funding identified by these methods does not specify the maintenance activity to receive the funding. Data elements for activity directed funding will be described below.

The general funding models utilize a simple set of data elements in order to arrive at a prediction for annual need. Depreciation, formula funding, and BRCI methods are dependent on age of the facility and current replacement value. The facility formula funding method utilizes functional use, square footage, and current replacement value. The empirical method uses a variety of data including: the condition index, current replacement value, age, building use type, and area. The following paragraphs will describe in detail each of the data elements used.

3.3.1.1 Building Age - This is determined directly by calculating for a given year the age of the facility via subtraction. The resulting ages of the study data are show in Table 3.2.

TABLE 3.2

BUILDING AGE
(1995 base year)

Building	Building No.	Age
Old Main	1	97
Blair Hall	3	84
Student Services	5	68
McAfee Gymnasium	7	58
Physical Science	8	57
Physical Science Addition	8	22
Booth Library	10	45
Booth Library Addition	10	27
Buzzard Building	19	38
Fine Arts Center	23	37
Fine Arts Addition	23	22
Life Science	29	34
Life Science Annex	29	34
Clinical Services	35	31
Coleman Hall	36	30
Coleman Addition	36	26
Physical Plant	22	30
Central Stores	14	22
Lantz Gymnasium	40	29
Lantz Phase 2	40	29
Lantz Phase 3	40	24
Klehm Hall	42	28
Klehm Addition	42	26
Lumpkin Hall	71	4

3.3.1.2 Building Condition Index - This is a numeric description of the building condition or deficiencies. It is based on an evaluation system developed at the University of Illinois in 1985 by Harlan Bareither. Each building is evaluated for deficiencies based upon the current usage. In many cases at Eastern Illinois University the facility usage has not changed significantly since the facility was constructed. This is often not the case at a major research university such as the University of Illinois at Urbana-Champaign. The research emphasis creates a constant flow of research funds to change facilities with irregular renovations in direct support of the research efforts but may also address major maintenance needs. Each building was evaluated by the following building construction categories:

1) Foundation (8 points);
2) Superstructure (13 points);
3) Exterior Skin (11 points);
4) General (29 points);
5) Plumbing and fire protection systems (6 points);
6) Heating, ventilating, and air conditioning systems (20 points);
7) Electrical, fire alarm, and lighting systems (13 points).

The rating of each building is based on 100 points. The maximum number of points attributable to each of the seven categories is shown above. The total points allocated to each construction category corresponds to its percentage of construction cost. The sum of the deficiency points applied to the replacement costs of the facility produced the estimated rehabilitation cost of the building. This will be described in more detail later in the chapter. Table 3.3 shows the condition indices for the sample in this study for two different analysis years, 1987 and 1995. There is no condition index for Lumpkin Hall in 1987 because it was not constructed until 1991.

TABLE 3.3

BUILDING CONDITION INDEX

Building	Building No.	1987	1995
Old Main	1	55	36
Blair Hall	3	50.5	51
Student Services	5	30.5	49
McAfee Gymnasium	7	55	67
Physical Science	8	41	53.5
Physical Science Addition	8	26	38
Booth Library	10	51	61
Booth Library Addition	10	31	41.5
Buzzard Building	19	73	69
Fine Arts Center	23	38.5	55
Fine Arts Addition	23	29	40.5
Life Science	29	35.7	33
Life Science Annex	29	26.5	47
Clinical Services	35	22.5	30
Coleman Hall	36	37.5	39
Coleman Addition	36	38	40
Physical Plant	37	38	30.5
Central Stores	54	26	38.5
Lantz Gymnasium	40	49	56
Lantz Phase 2	40	26	33
Lantz Phase 3	40	21	32
Klehm Hall	42	33.5	43
Klehm Addition	42	32.5	43
Lumpkin Hall	71	-	2

3.3.1.3 Building Replacement Cost - The building replacement cost is the estimated cost to replace the existing facility as it is presently used in current dollars. The Illinois Board of Higher Education (IBHE) provides estimates of replacement cost as of January of the year to the universities annually in May. These estimated costs are in dollars per gross square foot ($/gsf) and are provided to the IBHE from the state's construction agency, the Capital Development Board (CDB) based on actual state-wide expenditures. The costs vary by space type as defined in the National Center for Education Statistics Postsecondary Education Facilities Inventory and Classification Manual, 1992. In addition, gross square footages are derived via a

NASF to GSF multiplier which is a combination of net assignable to gross values and volumetric considerations. The estimated costs applicable to fiscal year 1995 is shown in Table 3.4.

TABLE 3.4

ILLINOIS BOARD OF HIGHER EDUCATION
FACILITY COST INDEX

Space Type	Room Type	Multiplier	January '95 $/GSF
Classroom	100	1.50	135.24
Instructional Lab (Dry)	200	1.64	151.50
Instructional Lab (Wet)	200	1.64	160.20
Research Lab (Dry)	200	1.67	201.85
Research Lab (Wet)	200	1.67	212.20
Office	300	1.70	140.00
Study (<1,400 SF)	400	1.70	136.35
Study (>1,400 SF)	400	1.40	136.35
Special Use	500	1.80	135.30
General Use	600	1.90	161.65
Supporting Facilities	700	1.20	126.30
Medical Care	800	1.70	212.23
Residential	900	1.70	145.79

Net assignable area is "the total floor area of the room available to the assigned occupant or use." (NCES, 1992) Assignable area differs from net area of a building as it does not include those floor areas which cannot be used by an university program. Nonassignable spaces include: *building service area*, restrooms, custodial closets, and other activities which support "cleaning and public hygiene functions"; *building circulation area*, corridors, stairs, elevator shafts, i.e., "all areas required for physical access to floors or subdivisions of space within the building"; and *mechanical area*, electrical and/or telecommunications closets, mechanical equipment rooms, utility shafts and chases.

In this study a facility database of buildings, rooms, room type, and area in net assignable square feet (NASF), was utilized. A program was written which summed the gross square footages in each building by the applicable unit replacement cost in (FY'95) dollars. The result of this calculation is shown in Table 3.5.

TABLE 3.5

BUILDING CURRENT REPLACMENT VALUE
(1995)

Building	Building No.	Current Replacement Value
Old Main	1	$11,876,320
Blair Hall	3	$4,502,856
Student Services	5	$6,046,687
McAfee Gymnasium	7	$15,338,728
Physical Science	8	$9,600,117
Physical Science Addition	8	$12,922,870
Booth Library	10	$8,483,108
Booth Library Addition	10	$13,200,014
Buzzard Building	19	$20,360,409
Fine Arts Center	23	$11,942,543
Fine Arts Addition	23	$7,631,753
Life Science	29	$9,512,908
Life Science Annex	29	$2,452,977
Clinical Services	35	$2,584,609
Coleman Hall	36	$6,339,616
Coleman Addition	36	$9,239,491
Physical Plant	37	$3,598,087
Central Stores	54	$2,752,353
Lantz Gymnasium	40	$26,847,191
Lantz Phase 2	40	$17,437,301
Lantz Phase 3	40	$1,289,591
Klehm Hall	42	$10,414,003
Klehm Addition	42	$3,960,973
Lumpkin Hall	71	$10,049,641

Another method to determine the replacement cost is to utilize historic information such as the original building construction cost and to escalate the costs based on an accepted valuation factor for construction costs. In the case of Kraal (1992), Markel's Handy Appraisal Chart was utilized to obtain valuation factors to estimate replacement costs. The method used is described in Sherman & Dergis, 1984. In this study, the buildings constructed after 1945 utilize Means Building Construction Cost Data, 1995; those constructed before 1945 are excluded. Table 3.6 shows the results of this method of evaluation.

TABLE 3.6

ESTIMATED REPLACEMENT COST
USING HISTORICAL COST INDICES
MEANS CONSTRUCTION COST DATA

Building	**Building No.**	**Current Replacement Value**
Old Main	1	N/A
Blair Hall	3	N/A
Student Services	5	N/A
McAfee Gymnasium	7	N/A
Physical Science	8	N/A
Physical Science Addition	8	$12,751,577
Booth Library	10	$16,343,594
Booth Library Addition	10	$9,199,576
Buzzard Building	19	$11,235,955
Fine Arts Center	23	$6,830,601
Fine Arts Addition	23	$5,438,493
Life Science	29	$7,033,782
Life Science Annex	29	$1,806,086
Clinical Services	35	$2,315,920
Coleman Hall	36	$5,322,234
Coleman Addition	36	$7,185,039
Physical Plant	37	$1,097,989
Central Stores	54	$1,287,255
Lantz Gymnasium	40	$13,302,326
Lantz Phase 2	40	$3,716,216
Lantz Phase 3	40	$1,271,207
Klehm Hall	42	$8,627,423
Klehm Addition	42	$2,545,276
Lumpkin Hall	71	$7,300,415

3.3.1.4 Building Use Type - Building use was determined based on actual space database kept for the campus by the Physical Plant. A correlation between university space identifiers and US Army space identifiers, as described and classified by the Neely & Neathammer study was done. A group of building use types were proposed to the author by Robert Neathammer (1995) following discussions about the CERL research and how it would be useful for colleges and universities. All evaluated US Army building uses are drawn from permanent facilities as opposed to temporary facilities which are constructed for short term use or capable of being easily relocated. Table 3.7 shows the NCES classification use types and Table 3.8 shows the USA-CERL building classifications selected for this study. Not all of the USA-CERL building classifications would be used in the final analysis but are included here for completeness.

TABLE 3.7

COLLEGE AND UNIVERSITY SPACE USE TYPES
NCES 1992

Space Type	Code	Examples
Classroom	100	classroom, classroom service
Dry, Inst. Lab	210	class laboratory, class lab service
Wet, Inst. Lab	220	class laboratory, class lab service
Dry, Res. Lab	250	research/nonclass laboratory
Wet, Res. Lab	260	research/nonclass laboratory
Office	300	office, conference room
Study, < 1400 sf	400	study room
Study, > 1400 sf	450	library, open-stack, processing room
Special Use	500	armory, field bldg., animal quarters
General Use	600	assembly, exhibition, lounge, meeting
Support Space	700	central computer, maintenance, garage
Medical Care	800	patient bedroom, nurse station, surgery

TABLE 3.8

USA-CERL BUILDING USE CLASSIFICATIONS

Code	Building Description and Use
P2	BN Classrooms, BN Administration & Classroom, BN HQ
P3	CO HQ Bldg, Administration & Support
P4	General Instruction, Learning Resource Ctr.
P5	Flight Simulator, Band Training, Applied Instr., Army Res. Ctr.
P7	Maintenance Hanger, Field Maintenance Shop, Paint Shop
P8	Vehicle Maintenance Shop, Electric Maintenance Shop
P9	Vehicle Depot, Quality Assurance Facility
PB	Maintenance Shop, I&R Warehouse
PE	Cargo Building, Storehouse, General Purpose Warehouse
PI	Hospital, Clinic, Laboratory, Morgue
PK	Clinic with or without Beds
PL	General Purpose, Post Headquarters, Division HQ, Engineer
PN	Offices for General, Colonel, LTC, Major, NCO/Enlisted
PU	Enlisted Dining Facility, Officer Dining Facility
Q4	Post Office, Auditorium/Theater
Q5	Entertainment Workshop, Drama Center, Theater w/dressing rms
Q9	Audio/Photo Club, Arts & Crafts Center
QA	Continuing Education Facility
QB	Physical Fitness Center, Gymnasium, Handball Courts
QD	Community Service Center, Library

There are several buildings at the Eastern Illinois University campus which have multiple use types within them. An example is Old Main which is consists of 26,594 net assignable square feet of various administrative office functions, and 15,739 net assignable square feet of mathematics department offices and classrooms. In order to accurately describe which NCES space type correlates to which USA-CERL building use each area is considered separately later in this study.

3.3.1.5 Building Area - The building area was drawn from the University's records on building square footages. The building records contained two sets of area information. Each building record had a total gross square footage which is derived by measuring all building floor area from exterior wall to exterior wall. In cases where a partial floor or basement exists the intermediate exterior wall is used. In addition, each building record contains a total net assignable square footage for the building. This is a mix of different space types as defined by the NCES classifications. The IBHE uses NASF to GSF factors in its annual assessment of the value of campus space. The factor includes adjustments for support spaces as well as volumetric considerations. It is possible to have different measured gross square footage and calculated gross square footage. Where calculated gross square footage values differ from the actual gross square footage of the building, the actual value was used. Table 3.9 shows the gross square footage values for each building.

TABLE 3.9

BUILDING AREA

Building	Building No.	NASF	Area (gsf)
Old Main	1	42,333	66,405
Blair Hall	3	16,113	27,060
Student Services	5	22,211	32,400
McAfee Gymnasium	7	52,577	68,712
Physical Science	8	32,375	46,784
Physical Science Addition	8	42,677	68,761
Booth Library	10	33,686	50,102
Booth Library Addition	10	52,822	90,333
Buzzard Building	19	71,144	100,529
Fine Arts Center	23	38,288	61,300
Fine Arts Addition	23	24,302	44,101
Life Science	29	30,525	46,056
Life Science Annex	29	7,838	14,282
Clinical Services	35	7,577	14,808
Coleman Hall	36	23,832	47,500
Coleman Addition	36	33,852	65,500
Physical Plant	37	18,662	20,815
Central Stores	54	13,915	17,848
Lantz Gymnasium	40	91,142	138,335
Lantz Phase 2	40	59,173	62,119
Lantz Phase 3	40	4,877	8,675
Klehm Hall	42	36,237	65,512
Klehm Addition	42	13,450	17,063
Lumpkin Hall	71	36,138	58,580

3.3.1.6 Summary of Data Elements - The five data elements presented above are independent variables used in several different building maintenance models to determine annual funding needs for major maintenance activities. These independent variables are used alone, or in combination, to calculate the funding level. They do not identify which specific portion of a facility requires the major maintenance expenditure and in some cases do not identify the building, from a group of buildings, which should receive major maintenance expenditures. The next section will identify and discuss data elements used by major maintenance funding methods which by their nature specify the maintenance activity.

3.3.2 Description of Specific Data Elements

Specific data elements are used in funding models to identify which area or component of a building requires major maintenance expenditures and in some cases when. The data elements described below are used in these models.

3.3.2.1 Building Subsystem Data - Building subsystems are the individual components which make up the building such as roofing, exterior cladding, interior partitions, HVAC, and other systems. Data from this area was used to determine the annual maintenance costs required following the Biedenweg & Hutson (1982) model. An example of how this model was applied to a hypothetical building constructed in 1950 with systems described above appears in Table 3.10.

TABLE 3.10

SIMPLIFIED EXAMPLE OF THE
BIEDENWEG & HUTSON MODEL
APPLIED TO A 1950 BUILDING
(all dollar values in thousands of 1980 dollars)

Year	Roofs 40-year life $12/sqft	Int. Part. 30-year life $5/sqft	HVAC 20-year life $10/sqft	Other 10-year life $2/sqft.	Total
1960				$20	$20
1970			$100	$20	$120
1980		$50		$20	$70
1990	$120		$100	$20	$240
2000				$20	$20
2010		$50	$100	$20	$170
2020				$20	$20
2030	$120		$100	$20	$240
2040		$50		$20	$70
2050			$100	$20	$120
2060				$20	$20
2070	$120	$50	$100	$20	$290
2080				$20	$20

Source: Biedenweg & Hutson: Before the Roof Caves In: A Predictive Model for Physical Plant Renewal - Part II, p. 9.

3.3.2.2 Building Component Data - Building components are the individual pieces which make up the building subsystems. Exterior finishes are comprised of brick, stone, windows (both fixed and operable), and other special features. Data from this area was used to determine the annual costs required from USA-CERL data and with a life-cycle cost modeling system developed by ASTM. A review of facility as-built documents from Physical Plant records was performed to obtain the detailed information required. This data is then used as input to the factors in the ASTM system. A complete listing of the ASTM raw factors appears in Appendix A. An example of the factors which are used in a detailed life-cycle cost analysis model appear in Table 3.11.

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TABLE 3.11

EXAMPLE ANNUAL MAINTENANCE COSTS
USING ASTM (USA-CERL)
BUILDING COMPONENT MODEL

Component Description	UM	Yrs	Labor	Material	Equipment
Architecture					
Exterior Wall					
Exterior Finishes					
Clay Brick First Floor	SF	500	1.09213	1.52801	0.54607
Concrete Block Second Flr.	SF	500	0.23465	1.05765	0.11733
Wood, Finished 1 coat 1 Fl	SF	125	0.33124	1.15597	0.18109
refinish wood ext. wall		5	0.04119	0.07972	0.04119
Exterior Doors					
Metal Doors					
Aluminum (Plain/Anodized)	CT	65	2.23574	332.17500	2.23574
Steel (unpainted)	CT	80	2.26369	182.03190	2.26369
Wall Finishes					
Gypsum and Plaster					
Sheetrock (unstippled)	SF	300	0.03497	0.39330	0.02678
Paper, Plastic, Fabric					
Wallpaper	SF	20	0.02925	0.53148	0.02925
HVAC					
Heating Generation					
Equipment					
Boiler Gas 250 Kbtu/hr	CT	30	65.0000	3972.8130	32.50000
Finned Radiator, Wall 10 F	CT	20	5.20000	328.85325	2.60000
Electrical					
Power System					
Cir. Bkr., Fixed < 599V 3P	CT	250	0.75049	110.28210	0.75049
Plug Fuse	CT	35	0.10400	0.39861	0.10400
Alarm System					
Fire Alarm System					
Smoke Detector	CT	15	0.41470	98.32380	0.41470
Fire Alarm Cont. Panel	CT	15	1.76150	1062.9600	1.76150

3.3.2.3 Building Construction/Renovation History - The following data are utilized in this section: initial occupancy date, the year the constructed building was occupied; initial capital investment, the original cost of construction; building renovation history, the year and actual cost of building renovations which have occurred since the original construction; historical cost adjustment factors as described above; and total capital investment, capital funds not operations and maintenance funds, in actual dollars. This material was obtained through investigations of the Eastern Illinois University Archives and Physical Plant records. Much of this information is spotty because of poor record-keeping practices. As a result, it is assumed that no significant renovations occurred in existing buildings prior to 1950. This assumption is based on a review of campus history in the archives and observation of systems in the older buildings which appeared either as would have been originally constructed or were installed following World War II.

3.3.2.4 Campus Operations and Maintenance Budgets - These are the total operations and maintenance budgets received annually for all state-supported facilities on the campus. They include budgets for personnel (direct labor), replacement parts and other materials to operate and maintain the facilities. The IBHE defines repairs and maintenance as "all activities and costs associated with routine, recurring repairs which keep a facility or asset in ordinarily efficient operating condition or preserve or restore property to its intended use without appreciably prolonging its useful life or adding to its value. Normal recurring maintenance and preventive maintenance are included." Separately identified in the annual O&M budgets is a budget line called Permanent Improvements. This is defined by the IBHE as being "those activities and costs, funding with operating funds [non-capital funds], which improve property or replace an item which has surpassed its estimated useful life". Capital funds are those which are not part of the institution's annual budget and are specifically appropriated for major efforts, typically construction. Capital funds are supported by the sale of bonds and must be expended on "durable" items which will meet or exceed the term of the bonds, typically greater than 15 years. O&M budgets also include costs associated with providing public safety for the campus, the University

Police Department. These costs are removed because they do not contribute to the condition of building maintenance.

3.3.3 Data Collection

All data was collected from records available at Eastern Illinois University. Building age and original cost information was obtained from the university archives. The Budget Office provided information about building areas and IBHE formulas. The Physical Plant provided information about building components and quantities through its record drawings of buildings. In some cases, changes occurred during the construction of buildings and the drawings are not an accurate reflection of the facility in use. In these cases, building tours confirmed or modified the actual data elements. Likewise, not all physical plant information (drawings or specifications) identified building elements, types, or quantities necessary to meet the models' data requirements. In these cases, the building tours were also used to verify quantities and specific material types in order to distinguish between different choices available.

Building deficiency information was collected from two studies conducted by the Eastern Illinois University Physical Plant in 1987 and 1995. Building replacement cost information was collected from annual reports to the IBHE as prepared by the Budget Office of Eastern Illinois University. Building subsystem data was collected through facility inspections by staff engineers and craft supervisors. The 1987 study was further validated by independent architects and engineers investigating a representative sample of facilities and comparing evaluation results. Building construction/renovation history was collected from the University Archives and from

Physical Plant department documents. Campus operations and maintenance budgets were obtained from both university internal budgets and annual Resource Allocation & Management Plan(s) (RAMP) submitted to the IBHE as well as from annual IBHE budget recommendations to the Governor and Legislature.

3.3.4 Actual Expenditures for Building Maintenance

Campus financial records provided a list of expenditures for major maintenance between 1957 and 1995. These records included expenditures from University operating funds and from specific capital allocations from the State of Illinois. Tables 3.12 through 3.16 show expenditure data in different formats which are used in the study.

TABLE 3.12

UNIVERSITY EXPENDITURES FOR REPAIRS, RENOVATION, AND IMPROVEMENTS BETWEEN 1957 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1957	$0	$0
1958	$15,500	$87,146
1959	$20,000	$109,534
1960	$8,400	$45,070
1961	$12,000	$64,061
1962	$10,000	$52,327
1963	$26,500	$135,316
1964	$20,000	$99,717
1965	$26,000	$126,645
1966	$31,000	$144,348
1967	$34,500	$155,177
1968	$43,650	$185,293
1969	$51,750	$203,345
1970	$37,070	$136,526
1971	$26,088	$85,903
1972	$39,262	$119,253
1973	$38,250	$107,242
1974	$35,299	$90,123
1975	$52,008	$122,706
1976	$20,000	$45,075
1977	$30,700	$65,555
1978	$36,500	$72,113
1979	$43,080	$78,781
1980	$0	$0
1981	$64,800	$97,848
1982	$108,000	$150,008
1983	$111,000	$146,293
1984	$114,200	$147,207
1985	$123,500	$158,038
1986	$182,500	$229,100
1987	$170,000	$204,892
1988	$250,000	$293,938
1989	$336,900	$386,649
1990	$190,000	$212,969
1991	$83,700	$91,396
1992	$116,500	$123,884
1993	$100,000	$103,933
1994	$150,000	$151,868
1995	$100,000	$100,000

TABLE 3.13

EXPENDITURES WITH STATE CAPITAL FUNDS FOR REPAIRS AND RENOVATION BETWEEN 1972 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1972	$0	$0
1973	$0	$0
1974	$0	$0
1975	$1,893,502	$4,467,481
1976	$0	$0
1977	$212,638	$454,057
1978	$114,000	$225,230
1979	$1,127,990	$2,062,778
1980	$455,395	$765,266
1981	$342,059	$516,509
1982	$0	$0
1983	$0	$0
1984	$326,200	$420,480
1985	$0	$0
1986	$0	$0
1987	$0	$0
1988	$1,158,049	$1,361,577
1989	$43,911	$50,395
1990	$1,152,541	$1,291,873
1991	$76,842	$83,907
1992	$0	$0
1993	$872,480	$906,796
1994	$309,584	$313,439
1995	$0	$0

TABLE 3.14

TOTAL EXPENDITURES FROM ALL SOURCES REPAIRS, RENOVATION, AND IMPROVEMENTS BETWEEN 1957 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1957	$0	$0
1958	$15,500	$87,146
1959	$20,000	$109,534
1960	$8,400	$45,070
1961	$12,000	$64,061
1962	$10,000	$52,327
1963	$26,500	$135,316
1964	$20,000	$99,717
1965	$26,000	$126,645
1966	$31,000	$144,348
1967	$34,500	$155,177
1968	$43,650	$185,293
1969	$51,750	$203,345
1970	$37,070	$136,526
1971	$26,088	$85,903
1972	$39,262	$119,253
1973	$38,250	$107,242
1974	$35,299	$90,123
1975	$52,008	$4,590,187
1976	$20,000	$45,075
1977	$30,700	$519,612
1978	$36,500	$297,343
1979	$1,483,080	$2,141,559
1980	$516,200	$765,266
1981	$64,800	$614,357
1982	$108,000	$150,008
1983	$111,000	$146,293
1984	$440,400	$567,687
1985	$123,500	$158,038
1986	$182,500	$229,100
1987	$688,203	$204,892
1988	$1,203,157	$1,655,515
1989	$336,900	$437,044
1990	$282,400	$1,504,842
1991	$365,400	$175,303
1992	$295,200	$123,884
1993	$1,445,500	$1,010,729
1994	$1,458,300	$465,307
1995	$712,100	$100,000

TABLE 3.15

EXPENDITURES FOR NEW FACILITIES BETWEEN 1973 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1973	$442,058	$1,239,404
1974	$393,683	$1,005,128
1975	$190,990	$450,617
1976	$0	$0
1977	$0	$0
1978	$0	$0
1979	$0	$0
1980	$0	$0
1981	$0	$0
1982	$0	$0
1983	$0	$0
1984	$0	$0
1985	$0	$0
1986	$0	$0
1987	$0	$0
1988	$0	$0
1989	$0	$0
1990	$190,725	$213,782
1991	$6,461,500	$7,055,584
1992	$0	$0
1993	$0	$0
1994	$286,472	$290,039
1995	$217,950	$217,950

TABLE 3.16

EXPENDITURES FOR REPAIRS, RENOVATIONS, AND IMPROVEMENTS BETWEEN 1957 AND 1995 FOR SIX BUILDINGS

Building	Actual Expenditure	Expenditure (1995$)
Fine Arts	415,757	511,678
Life Science	138,817	191,490
Coleman Hall	1,842,819	3,683,574
Klehm Hall	119,874	134,589
Lantz Gym	0	0
Physical Plant	17,996	128,281

3.4 Description of Models Examined in the Study

This section provides a description of the specific procedures used to construct and analyze the models used in this study.

3.4.1 Building Condition

Each building was evaluated on a 100 point scale using the Bareither evaluation form. Based on the general nature of the evaluation form it is necessary that persons with thorough knowledge of buildings, building components, and architecture/engineering perform the evaluation. Some evidentiary indicators may in be based on other factors such as operating experience and maintenance history. The form and means of gathering the data recognize that a knowledgeable person can distinguish between these indicators and make the appropriate evaluation of building condition.

The results of the building condition survey used here were derived from two evaluations with supplemental information on operating and maintenance history provided anecdotally. Insufficient information existed to draw from operating and maintenance records to replace a building survey.

The building condition scale is divided into seven primary construction categories described below. This evaluation system is not based on code compliance costs. A copy of the evaluation form is included in Appendix B.

3.4.1.1 Foundation

This section includes information relating to foundation settlement or differential movement. A maximum of eight points is assigned to this section. The point total reflects the value of initial construction costs and minor repairs to foundations on total facility costs. Any serious foundation problem has a reciprocal effect in other building systems and subsequent points are assigned there in those portions of the evaluation.

3.4.1.2 Superstructure

Structural problems, such as inadequate or overloaded structural elements are addressed in this section. Some of the symptoms identified in this section (roof ponding) may really have a basis in other sections but are correctable through structural modifications. More serious problems that are structural in nature, such as missing expansion joints resulting in "broken or cracked walls" receive five of the maximum thirteen points available to this section. This is a reflection of the high cost associated with repair of such problems but also the general durability of the building to resist subsequent environmental damage over the normal life of a building, 50 years.

3.4.1.3 Exterior Skin

All the portions of the building which resist weather are included here. Roofs, which are one of the more common facility problems (and seldom deferred very long) are covered in this section. Also included are areas of windows and tuckpointing or related joint failures. A maximum of eleven points is available here.

3.4.1.4 General

This refers to many of the interior conditions. Painting, as an example, is a concern because of its highly visible importance to building occupants yet it receives only two points out of the maximum 29 available. Flooring, including tile or carpet, and ceilings are also addressed here. This section includes accessibility issues such as elevators and ramps as well as general safety such as fire exit locations and stairways. These latter two issues may be more code related, rather than fundamental to the original construction, but affect the cost of any reconstruction/rehabilitation greatly since the newer code must generally be addressed. In this case these items are highlighted due to their more extensive or expensive nature in construction and facility maintenance. Also included in this section are the costs of rearranging walls resulting from upgrades or improvements to building use and utilization.

3.4.1.5 Plumbing and fire protection systems

This section claims a maximum of six points. Replacement of waste and vent lines or code issues of a sprinkler system each claim one-third of the total. Fixture replacement or the need for handicap fixtures may also be addressed here. Compliance to changing codes and standards is not the major thrust of these evaluation elements. Most plumbing appears in limited areas of a facility but has a high concentration of costs. Restrooms are a clear example of this. Sprinkler systems, on the other hand, are widely distributed throughout the facility but are of low component cost. Thus the equal weighting, at 2 points each, of these three areas appears reasonable.

3.4.1.6 Heating, ventilating, and air conditioning systems

The HVAC system, which includes temperature controls, receives a maximum of 20 points. These are a small but clearly significant portion of any building. Even in older structures, a well operating HVAC system can reduce incidents of indoor air quality (IAQ) problems despite not meeting current construction standards intended to provide good indoor air quality.

HVAC, by its very nature is both highly concentrated and widely distributed. As a result these systems command a large portion of building initial and maintenance costs.

3.4.1.7 Electrical, fire alarm, and lighting systems

Electrical systems are allotted a maximum of thirteen points. The bulk of this is for distribution which includes quantity of receptacles throughout the building, sufficiency of sub-panels, and control of the various circuits. Overall building capacity rates only one point. This is because capacity can be increased without much additional cost but a great deal of work must be done to add to the distribution of power in the building. Increases in electrical consumption resulting from new and additional equipment may result in the need for increased capacity but more likely in the need for additional service receptacles.

The building condition model gives a clear, after-the-fact, review of the condition of a facility. It is used in this study to provide an independent assessment of the condition of each building evaluated. It cannot make predictions as to where the condition of the facility will be in the future. Other methods must be used as predictions. When viewed from a historic perspective, the building condition model allows for a comparison of the predictive models against actual conditions.

3.4.2 Age Ratio and Depreciation Methods

One method of funding allocation, the Sherman-Dergis Model is recommended for university use. This is similar to a reverse sum-of-years' digits depreciation method utilized by Phillips (1986). Depreciation methods have been studied in more detail by Kraal (1992). While advocating the Age Ratio Model and Straight Line Depreciation method as being representative of actual building needs, Kraal identifies the Age Ratio method as being more information intensive and thus more difficult to apply. Advocates of this method believe it is more representative of actual building needs due to its heavier weighting of funding needs towards the end of the building's useful life rather than a more linear method.

In this method the sum-of-years' is determined by summing the total number of years of estimated building life. In the case of an assumed 50-year life the sum-of-years' digits is 1275. The equation used is then:

$$C = R * n/S * 67\%$$

where: C is the annual capital renewal expenditure

R is the replacement value of the facility

n is the age of the facility

S is the sum-of-years' of assumed facility life

The result is reduced to 67% following the assumption that the maximum cost of building renovation will not exceed 67% of the total replacement value. In the case of a facility with an age of 15 years, assumed life of 50 years, and replacement value of $10,000,000 the predicted annual capital renewal expenditure is $78,824. There is also an allowance in this model to reflect previous renovation activities to a facility. This adjustment has the same effect as reducing the building age. Examples in Kraal (1992), and Phillips (1986), describe this process in detail.

In the case of the Depreciation Model, a simple spreadsheet analysis of building replacement costs can be used to identify the annual financial needs associated with major repairs and rehabilitation expenses. The Age Model requires slightly more information but can also be performed with a spreadsheet utilizing the financial functions which are typically found in these applications. The use of a computer to perform the annual analysis is essential regardless of the method used.

3.4.3 Building Subsystem (BRCI) Model

This method utilizes the understanding that building systems have a predictable life and cost which can then be related to facility replacement value. A model utilizing this method was described by Biedenweg & Hutson (1984). The model requires that sufficient information regarding the construction of the building is known or that building materials of a similar function have a similar life. Another way of viewing this is to have buildings which are similar in overall composition of materials. This may be difficult to assume when a campus has grown over several decades and has not made use of design and construction standards, a relatively new concept in campus maintenance. In the worst case, individual tables of building replacement costs and cycles are required. The ideal case utilizes a single table of building replacement costs and cycles similar to that shown in Table 3.10. A table of component replacement costs and cycles for the analysis is shown in Table 3.17. The replacement costs and cycles for the BRCI model were developed using percentages of building composition from Bareither's building condition index model and life cycles from Neely & Neathammer. The table reflects the overall percentage of expenditure over a fifty year period posited by Bareither when developing the building condition index model.

TABLE 3.17

BRCI REPLACEMENT COSTS AND CYCLES

Component	Percent of CRV	Replacement Cycle
Roofs	2	30
Interior Paint	1	12
Windows	4	50
Tuckpointing	1	25
Floor	1	10
Ceiling	1	65
Wall Alignment	5	50
Plumbing Fixtures	2	50
Waste Lines	1	50
Plumbing Lines	1	50
Fire Sprinklers	1	20
Heating	3	30
Ventilation	3	20
Air Conditioning	3	30
Temperature Controls	1	20
Electric Distribution	3	25
Electric Fixtures	1	25
Fire Alarm System	1	20
Other	2	10

3.4.4 Building Component/Life-Cycle Cost Model

This model utilizes individual building components: brick, concrete, plaster, gypboard, radiators, and terminal reheat units to assemble predictive information about maintenance costs and replacement timeframes. This model is described by Heidler (1994) and Neely & Neathammer (1991). Heidler's model makes use of inflation adjustment methods, future value, present value, etc. on the actual cost of the building component to predict the funding level needed in the future. Neely & Neathammer have systematized the model to the point where tables of annual maintenance costs, in terms of employee hours per unit, material costs per unit, and support equipment costs per unit are applied to a wide and detailed variety of building components. These are all aggregated through a large database of building and material information to make predictions about life-cycle costs. Adjustments for employee efficiency are not made. Man-hour costs for employees is automatically incorporated into this system.

This method is sensitive to the predicted life of the building components and develops errors quickly when the age of the component does not match with the prediction. An example of differences between predicted component life can be found by comparing "suggested average useful life of facility components" by Heidler (1994) and life cycle cost predictions by Neely & Neathammer, described in further detail below. An aluminum frame window of $100 installation value was used. Heidler suggests a useful life of 15 years, Neely & Neathammer suggest 75 years for aluminum. Thus the future value, assuming 4% inflation, of the aluminum frame window at its replacement age of 15 vs. 75 years is $180 vs. $1,895. It should be pointed out at this stage that Heidler may be assuming virtually no annual maintenance is performed on the window while Neely & Neathammer recommend annual procedures and expenses for maintenance.

ASTM has published a building maintenance, repair, and replacement database (BMDB) for life-cycle cost analysis from the research of Neely & Neathammer, 1991. In their research Neely and Neathammer investigated 10 US Army facilities over an eight year period. The installations studied represented about 8% of the entire US Army holdings and contained a wide variety of building uses from storage facilities to hospitals. The study developed five different databases based on the amount of information available for maintenance predictions. They were:

1) Predict an annual cost when only the building floor area is known.

2) Predict an annual cost when the floor area and the current functional use is known.

3) Predict an annual cost when the floor area, current use, and age of the facility are known. Report the costs to two components; replacement tasks and all other tasks combined.

4) Predict the total labor hours, equipment hours, labor cost, material cost, and equipment cost when the floor area, current use, age, and average cost for labor and equipment per hour are given.

5) Predict the labor hours, equipment hours, labor cost, material cost, and equipment cost for each trade or shop when the floor area, current use, age, and individual shop costs for labor and equipment per hour are given.

They drew on 120 years of data on building maintenance costs. These costs were exclusive of utility, cleaning, or site work costs. A square footage summary of the various databases appears below, all values are provided in 1985 dollars in the Washington, DC area and must be adjusted for inflationary and location factors. The ASTM publication provides adjustments for location within the United States.

Average annual cost per square foot - $1.29

Average annual cost per square foot by facility current use Table 3.18

TABLE 3.18

AVERAGE US ARMY COST BY FACILITY TYPE

Facility Description	Cost per GSF (1985 $)
General instruction buildings	1.17
Applied instruction buildings	1.10
Aviation unit maintenance hangers	1.11
Organizational vehicle maintenance shop	1.19
Support vehicle maintenance shop	1.46
Special-purpose maintenance shops	1.43
Maintenance-installation repair	1.54
Ammunition storage facilities	.52
Cold-storage facilities	1.54
General purpose warehouse	.80
Hospital	1.07
Dental clinic	1.82
Health clinic	1.43
General purpose administration	1.05
Family housing 1900 - 50	1.47
Family housing 1951 -	1.31
Family housing (Capeheart)	1.82
Family housing (Wherry)	1.52
Unaccompanied personnel housing: enlisted	.99
Trainee barracks	.89
Unaccompanied personnel housing: dining	1.41
Unaccompanied personnel housing: officers	1.32
Community fire station	1.33
Chapel center facilities	1.54
Auditorium/theater facility	1.33
Bowling center	.87
Child-support center	1.78
Commissary	1.19
Arts and crafts center	1.00
Physical fitness center	1.43
Transient housing facilities	1.82
Consolidated open dining facility	1.15
Community retail store	1.28

Separate tables were developed for each facility type to identify the Annual Recurring Maintenance (ARM) costs and Major Cost Tasks and Replacement Tasks (MRT). The values for an Administration Building area shown in Table 3.19 below. It is important to note the differences between ARM costs and MRT costs. Annual recurring maintenance costs are those which are non-replacement and "non-high" costs associated with maintaining a facility. Examples of those expenditures which represent MRT costs and are thus not part of ARM costs are: Place new membrane over existing built-up roof, refinish pointed clay brick exterior wall, replace aluminum roll-up door, repair coal boiler, repair hermetic chiller, or any other complete system replacement.

TABLE 3.19

REPLACEMENT AND OTHER TASK COSTS IN DOLLARS (1985) FOR ADMINISTRATION BUILDINGS MAJOR COST TASKS AND REPLACEMENT TASKS (MRT) (ARM = 1.31)

Decade				**Year**	**within**	**Decade**				
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.020	0.010	0.020	0.020	0.160	0.170	0.230	0.250
1	0.610	0.680	0.800	0.990	1.150	0.770	0.960	0.690	0.980	0.910
2	0.490	0.620	1.310	0.460	0.970	1.440	1.100	1.400	1.570	0.780
3	0.840	1.540	1.090	1.120	1.320	0.680	0.910	0.930	1.070	1.640
4	1.610	0.930	0.670	0.590	1.060	0.500	0.590	0.510	0.620	0.680
5	1.220	1.040	1.150	1.280	1.500	1.750	1.410	1.330	1.900	0.810
6	0.970	1.710	0.910	1.010	1.780	0.950	1.050	1.720	1.150	1.300
7	1.120	3.400	2.220	1.330	2.700	1.940	1.230	3.270	1.360	1.750

Table 3.19 shows that the total maintenance costs range between $1.31 and $4.71 per gross square foot in 1985 dollars over an eighty year life. Adjustments for inflation between 1985 and the study date must be accounted for in an analysis of an actual facility. When detailed material information is known and used material costs may be adjusted using standard inflation tables such as Means (1995) while employee costs must be adjusted using the actual hourly costs of specific trades for the date of study. In the case of square footage based applications all adjustments must be made

with standard inflation tables because the actual employees used and hours consumed are not known.

Additional tables for: General Instruction Buildings, Applied Instructional Buildings, Auditorium/Theater, Arts & Crafts Center, Continuing Education, Physical Fitness, and Organizational Vehicle Maintenance Facilities, appear below in Tables 3.20 - 3.26. In the analysis performed, these values were adjusted with the inflation rate determined by the IBHE annual cost data described above.

TABLE 3.20

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
GENERAL INSTRUCTION BUILDINGS
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.72)

Decade				**Year**	**within**	**Decade**				
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.010	0.030	0.000	0.010	0.140	0.220	0.230
1	0.380	0.360	0.270	0.260	0.390	0.440	0.270	0.430	0.500	0.370
2	0.410	0.480	0.230	0.210	0.340	0.410	0.380	1.880	2.390	2.000
3	3.000	2.000	1.810	0.640	0.410	0.260	0.250	0.490	0.490	0.690
4	0.570	0.470	0.500	0.310	0.350	0.250	0.220	0.320	0.460	0.370
5	0.640	0.650	0.680	0.570	0.510	0.760	1.020	2.480	2.140	2.530
6	3.310	1.990	2.030	0.630	0.830	0.510	0.610	0.770	0.750	0.870
7	0.900	0.840	0.640	0.570	0.620	1.040	0.500	0.590	0.660	0.590

TABLE 3.21

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
APPLIED INSTRUCTION BUILDINGS
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.80)

Decade				**Year**	**within**	**Decade**				
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.000	0.140	0.200	0.020	0.030	0.560	0.060
1	0.460	0.160	0.300	0.160	0.530	0.220	0.710	0.160	0.990	0.210
2	0.990	0.220	0.200	0.170	0.720	0.230	0.310	0.420	1.150	0.500
3	4.470	0.980	0.810	0.280	0.240	0.260	0.520	0.940	0.270	0.350
4	1.550	0.570	0.480	0.260	0.320	0.250	0.220	0.190	0.790	0.230
5	0.820	0.330	0.430	0.280	0.480	1.020	1.490	0.420	0.490	0.420
6	4.880	0.650	0.680	0.250	0.750	0.220	0.210	0.260	0.500	0.260
7	1.010	0.330	1.650	0.990	0.290	1.930	0.460	0.410	0.440	0.320

TABLE 3.22

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
AUDITORIUM/THEATER BUILDINGS
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 1.09)

Decade	Year within Decade									
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.060	0.060	0.000	0.000	0.500	0.400	0.030
1	0.220	0.170	1.010	0.430	0.890	0.610	0.590	0.560	0.900	0.170
2	0.380	0.310	0.470	0.710	2.060	0.710	2.070	1.050	1.220	0.900
3	1.350	0.600	1.220	0.190	1.620	0.190	0.590	0.910	0.270	0.960
4	1.340	0.330	0.750	0.320	0.750	0.250	0.080	0.630	1.280	0.200
5	0.420	0.375	0.880	2.080	1.110	1.130	2.580	0.900	1.350	0.290
6	1.050	0.500	1.330	2.070	0.690	0.430	0.640	0.270	0.950	0.620
7	0.700	0.770	0.940	1.230	0.760	1.590	0.240	0.490	1.270	0.720

TABLE 3.23

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
ARTS & CRAFTS CENTER
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.69)

Decade	Year within Decade									
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.020	0.040	0.000	0.010	0.140	0.090	0.060
1	0.100	0.140	0.190	0.540	1.060	0.720	0.160	0.240	1.120	1.050
2	0.210	0.330	0.390	0.120	0.320	0.210	0.690	0.210	3.330	0.880
3	2.170	0.330	0.380	0.360	0.320	0.330	0.700	1.000	0.230	2.010
4	0.520	0.180	0.880	0.640	0.400	0.310	0.090	0.200	0.440	0.160
5	0.810	0.500	1.020	0.160	0.670	0.760	3.160	1.180	1.260	0.710
6	1.940	0.150	0.250	0.170	0.600	0.440	0.270	0.280	0.170	0.260
7	1.790	1.020	1.080	0.950	0.280	1.690	0.280	0.370	2.070	0.260

TABLE 3.24

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
CONTINUING EDUCATION BUILDINGS
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.53)

Decade				Year	within	Decade				
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.010	0.010	0.000	0.000	0.010	0.020	0.010
1	0.070	0.080	0.080	0.100	0.300	0.130	0.160	0.300	0.620	0.400
2	0.360	0.210	0.220	0.220	0.230	0.290	0.390	0.340	1.000	0.430
3	1.480	0.360	0.440	0.470	0.410	0.470	0.840	0.400	0.420	0.480
4	0.460	0.180	0.420	0.190	0.230	0.250	0.210	0.200	0.260	0.280
5	0.490	0.480	0.470	0.710	1.040	0.830	1.400	0.780	0.520	0.530
6	2.180	0.610	0.560	0.400	0.500	0.540	0.670	0.410	0.500	0.490
7	1.310	0.420	0.960	0.540	0.410	1.130	0.610	0.520	0.500	0.420

TABLE 3.25

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
PHYSICAL FITNESS BUILDINGS
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.85)

Decade				Year	within	Decade				
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.000	0.040	0.010	0.060	0.370	0.260	0.360
1	0.220	0.510	0.310	0.810	0.450	0.400	0.310	0.480	0.490	0.470
2	0.880	0.540	0.210	0.210	0.470	0.590	1.420	0.740	0.320	1.400
3	1.040	0.850	0.560	0.410	0.560	0.280	0.430	0.740	0.370	1.260
4	2.020	1.110	0.140	0.540	0.460	0.290	0.150	0.570	0.360	0.570
5	1.040	0.760	1.020	0.870	0.970	0.590	0.800	0.820	1.010	0.940
6	1.390	1.020	0.540	1.000	0.490	0.760	0.520	0.900	0.420	1.450
7	0.770	0.800	0.690	0.530	0.570	0.730	0.800	0.810	1.420	1.040

TABLE 3.26

REPLACEMENT AND OTHER TASK COSTS
IN DOLLARS (1985) FOR
ORGANIZATIONAL VEHICLE MAINTENANCE FACILITIES
MAJOR COST TASKS AND REPLACEMENT TASKS (MRT)
(ARM = 0.96)

Decade	Year within Decade									
	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.050	0.080	0.020	0.150	0.140	0.220	0.130
1	0.290	0.440	0.540	0.430	0.640	0.430	0.440	0.300	0.440	0.420
2	0.480	0.580	0.360	0.370	0.620	1.000	1.970	0.750	1.770	1.260
3	1.530	0.850	0.490	0.510	0.370	0.600	0.490	0.530	0.450	0.820
4	0.660	0.410	0.450	0.810	0.460	0.320	0.350	0.300	0.580	0.540
5	0.590	0.680	0.800	0.840	1.850	0.750	2.140	1.260	1.810	0.740
6	0.660	0.740	0.620	0.480	0.650	0.680	0.730	0.890	0.620	0.660
7	0.770	0.920	0.800	0.870	0.690	1.060	0.620	0.720	0.880	0.960

3.5 Mathematical Techniques Employed

The building condition index (BCI) is used as an empirical device to measure the amount of deferred maintenance in a building. It is also used to make comparisons between different funding methods. Comparisons can also be made between actual expenditures and the predicted expenditures to determine the accuracy of the funding method.

All comparisons use that base year of 1995. Actual expenditures are adjusted to the base year using the Means Historical Cost Index (1995). The actual expenditures are subtracted from the predicted expenditures to arrive at a predicted building condition index (PBCI). If the PBCI is close to the actual building condition index (ABCI) then the funding method is considered more accurate than a method where the indices are not close. An accurate funding method will have a PBCI within 10 of the ABCI.

Comparison of non-linear models, Biedenweg and Hudson's BRCI and the USA-CERL method, against the linear depreciation and formulaic methods uses the principle of least squares. This technique creates a linear approximation of an otherwise complex function or dataset. The approximate function created by this method has sufficient accuracy to compare the other models described above so as to be suitable for this study.

As an example, the data available from the studies conducted at US Army bases provides a set of discrete points to which a function is to be applied. Based on the presentation of the data as shown in Tables 3.19 through 3.26, there are many discrete points with which to work in order to develop the approximating function. Each table presents 80 data points. It is known that a function will exist because for each of the 80 independent ages listed there is one, and only one, corresponding dependent annual cost.

The principle of least squares generates an approximate function $f(x_i)$ with a minimum residual for all x_i at known points and for all other possible points x. The principle is not suitable for extrapolation of data. Because the interpolated data is available for a dataset larger than the linear models it is compared with, then the interpolation should be sufficiently accurate for comparison.

3.6 Model Analysis

The analysis is divided into three parts. First, a review of the building renewal cost predictions resulting from the four predictive models, depreciation, formula funding, facility formula funding, with comparison to each other and total predicted funding need, and average cost projections. Then a comparison of the models to a predicted building condition index versus the actual building condition index as measured by the building audits of 1987 and 1995. The building condition index, based on audits of facilities, is used as a benchmark. Inflationary adjustments are made using the Means (1995) historic cost index.

The second part of the analysis compares the actual expenditures for major maintenance on the building inventory against model predictions for funding needs and building condition. The annual major maintenance needs which were not funded, as exhibited by shortfalls in funding, are summed to arrive at a deferred maintenance amount. A close correspondence between the predicted need and the actual need indicates that the predictive method can be confidently applied to building maintenance needs in order to control the accumulation of deferred maintenance.

The third part of data analysis compares the cycles of the component based models, Biedenweg & Hudson BRCI and USA-CERL square foot models, with each other in six facilities where detailed building information was available. The six buildings: Fine Arts Center, Life Science, Coleman Hall, Physical Plant/Central Stores, Klehm Hall, and Lantz are representative of higher education space types and were constructed between 1958 and 1972. They are typical of many buildings constructed throughout the United States when higher education space was growing rapidly. Detailed information on the construction of each of these facilities is used to determine yearly costs for major maintenance expenditures through 1995. Close correlation between the models will provide justification to utilize a model which draws on simpler building data rather than a more complicated and data intensive model.

3.7 Summary

This chapter presented the base data which will be examined in this study as well as the techniques which will be employed. The base data includes: the ages of the buildings, original cost of the buildings, size of the buildings, the condition of the buildings as a result of two inspections in 1987 and 1995, and the usage of the buildings by different occupants following a standard higher education classification system. The techniques employed include: direct application of models to the study data for direct comparison between model results and actual conditions and application of first and second order approximations of non-linear models.

Chapter 4 consists of the application and analysis of the models presented in this chapter and a discussion of the results of the studies as well as review of the predictions for future funding.

CHAPTER 4

DISCUSSION

4.1 Introduction

The purpose of this chapter is to explain the results of the data analysis plan described in Chapter 3. The analysis of the Depreciation, Formula Funding, Facility Formula Funding, BRCI, USA-CERL and Building Condition Index models is divided into two parts. The first part examines the differences between the models when they were used on data from the sample. Model outcomes are examined from three perspectives. First, total estimated funding needs for the period 1953 to 1995, second, average annual cost projections, and third, accuracy of the model to predict the building condition based on the actual expenditures between 1953 and 1995. The analysis of model outcomes involves comparisons among the four models as well as a comparison to the rule of thumb funding range of 1.5% to 3.0% of building replacement value discussed earlier. The Building Condition Index (BCI) is founded on actual observations and used as a baseline from which to compare the five funding prediction models.

The second part of the data analysis examines the effect of actual major maintenance expenditures on building inventory between the years 1972 and 1995 and compares them against model predictions of funding needs and building condition. Only those buildings constructed after 1957 are modeled. This selection permits the inclusion of over 65% of the sample's gross square footage based on original date of construction and avoids the incorporation of several of the older facilities in the sample. This is beneficial due to the lack of clear historical data on renovations and upgrades of facilities that may have occurred, prior to 1972, to the older buildings. It also eliminates the need to estimate an adjusted building age in accordance with a technique described by Sherman & Dergis, 1984. The period 1957 to 1995 permits simulation of building maintenance over most of a building life cycle, 38 out of 50 years. The Building Condition Index is used as a baseline. Annual major maintenance predictions that were not funded are summed to arrive at a deferred maintenance amount. The summation is made adjusted to the study year. This summation is then compared against the estimates for deferred maintenance predicted by the Building Condition Index.

A third part of this chapter is devoted to the cyclical maintenance funding models developed by Biedenweg & Hudson and Neely & Neathammer. In the latter case, the models were developed for US Army facilities. Neely & Neathammer claim the models are applicable to university facilities (1991). The three cyclical models are compared against the three formulaic models previously studied. A detailed component based funding model developed by Neely & Neathammer is studied on a limited set of buildings to see how it predicts funding needs versus the more generic models.

The fourth part of this chapter examines, through regression analysis, the detailed models to see how they compare with the rules of thumb funding recommendations. This part compares the average level of funding against current replacement value from the detailed models. It provides a normalized way to evaluate whether sufficient funds are made available. If a more detailed method accurately recommends funding different from the rules of thumb then there are grounds for changing the rules of thumb.

4.2 Description of the Data

The sample contained 24 buildings and was selected because it contained the data required to test all of the models examined, was readily available, and had sufficient information on building condition with which to compare results of predictive models. It contained a variety of the types of buildings found on college or university campuses. It included very simple buildings such as warehouse facilities and general classroom buildings and complex buildings such as science and medical facilities.

Four primary building characteristics employed by the models examined in this study are building age, condition, space classificaiton, and components. Table 4.1 provides the distribution of area by year of construction for buildings in the sample. Construction dates have been grouped in ten-year intervals to assist in comparing the distribution.

TABLE 4.1

AGE PROFILE OF SAMPLE

Decade	Area (GSF)
1895 - 1904	66,405
1905 - 1914	40,309
1915 - 1924	0
1925 - 1934	32,400
1935 - 1944	115,496
1945 - 1954	50,102
1955 - 1964	241,475
1965 - 1974	674,889
1975 - 1984	14,070
1985 - 1994	82,645

This table describes the age profile of the building inventory. The data indicate that the majority of gross area is represented by buildings constructed in a narrow time span. Fifty percent of the gross area of this sample inventory is contained in buildings constructed between 1965 and 1974, the eighth decade of the university. The sample size increases to 80 percent when a 50-year sample size is selected, buildings constructed since 1945. The most rapid period of growth for Eastern Illinois University was between 1957 and 1973 when 76 percent of the campus was constructed.

The second major characteristic employed by a model in this study is building condition. Table 4.2 provides a listing of replacement value, gross area and 1995 deferred maintenance rating by building. The ratings are a percentage of estimated replacement cost lost to the deferred maintenance as determined by a building audit. This is also the estimated percent of current replacement value necessary to restore the building to a like new operational state. This is also when the needs of the building occupants are met by the building design and operation. For a 100,000 gsf building with a replacement cost of $150.00/gsf and a rating of 33 it would require an investment in replaced or rehabilitated building equipment or materials of $5,000,000. A building with a rating in excess of 50 should be considered for demolition because of the large cost to rehabilitate the facility relative to the existing value.

TABLE 4.2

SAMPLE WITH BUILDING CONDITION (1995), BUILDING AREA (GSF), AND CURRENT REPLACEMENT VALUE (1995$)

	1995		Current
Building	**Rating**	**Area (gsf)**	**Replacement Value**
Old Main	36	66,405	$11,718,553
Blair Hall	51	27,060	$4,443,038
Student Services	49	32,400	$6,176,747
McAfee Gymnasium	67	68,712	$15,229,148
Physical Science	53.5	46,784	$9,521,229
Physical Science Addition	38	68,761	$12,751,577
Booth Library	61	50,102	$8,370,767
Booth Library Addition	41.5	90,333	$13,025,180
Buzzard Building	69	100,529	$20,090,377
Fine Arts Center	55	61,300	$11,792,673
Fine Arts Addition	40.5	43,344	$7,534,479
Life Science	47	46,056	$9,387,096
Life Science Annex	33	14,282	$2,420,513
Clinical Services	30	14,808	$2,550,300
Coleman Hall	39	47,500	$6,255,472
Coleman Addition	40	65,500	$9,484,905
Physical Plant	30.5	20,815	$3,958,087
Central Stores	38.5	17,848	$2,752,353
Lantz Gymnasium	56	138,335	$26,491,765
Lantz Phase 2	33	62,119	$17,206,565
Lantz Phase 3	32	10,465	$1,728,535
Klehm Hall	43	65,512	$10,275,921
Klehm Addition	43	17,063	$3,908,454
Lumpkin Hall	2	58,580	$9,916,210

The contents of Table 4.2 indicate that the overall condition of the buildings in the sample is quite bad. The total area shown is 1,234,613 square feet. The current replacement value (CRV) is $226,989,944 (1995$). Following previous descriptions of the building condition index (BCI) an estimated $105,406,187 of deferred maintenance exists in the sample. Table 4.3 summarizes this information by condition rating. The best facilities have ratings of less than 5, the average rating of buildings in the first decile is 1.92. Buildings in the first decile have an average age of 3.3 years. No buildings fall in the third decile. Most buildings fall in the fourth through sixth decile. The worst buildings have ratings in the 60's, seventh decile, with a maximum of 69. An average rating of 43.7 for those facilities listed in Table 4.2 indicates a campus of facilities in very poor condition. The "ideal" rating for an aggregate of buildings would be no worse than the ratio of recommended annual maintenance expenditure to the current replacement value. This will be discussed further later in the study.

TABLE 4.3

AVERAGE BUILDING AGE DISTRIBUTION
BY BUILDING CONDITION RATING

Condition	**Average Age (years)**
0 - 9	3.3
10 - 19	23.3
20 - 29	-
30 - 39	38.6
40 - 49	33.0
50 - 59	44.3
60 - 69	46.3
70 - 79	-
80 - 89	-
90 - 99	-

A third major characteristic used in modeling building maintenance needs is the space classification or description of activity and usage of spaces within the facility. The National Center for Education Statistics has used a system developed by Dahnke

(1968), the Postsecondary Education Facilities Inventory and Classification Manual (1992). This is the standard for reporting on university space and determining valuations for that space in Illinois. Table 4.4 shows the distribution of spaces in the sample following the NCES classification system.

TABLE 4.4

SPACE TYPES AND AREAS (1995)

Space Type	Room Type	NASF	Multiplier	GSF
Classroom	100	108,874	1.50	163,311
Lab, Instruction (Dry)	200	159,389	1.64	261,398
Lab, Instruction (Wet)	200	0	1.64	0
Lab, Research (Dry)	250	11,520	1.67	19,238
Lab, Research (Wet)	250	0	1.67	0
Office	300	217,462	1.70	369,685
Study, < 1,400	400	12,275	1.70	20,868
Study, > 1,400	400	61,278	1.40	85,789
Special Use	500	272,809	1.80	491,056
General Use	600	142,749	1.90	271,223
Supporting Facilities	700	74,151	1.20	88,981
Medical Care	800	2,729	1.70	4,639
Residential	900	882,533	1.70	1,500,306
Unassigned	-	0	1.70	0

Table 4.4 identifies all the different space types and quantities of space at Eastern Illinois University. The sample is a subset of these spaces and does not include residential space or several other areas that are non-state-supported. In addition, the sample does not include the smaller facilities (<10,000 gsf) that are included in Table 4.4; they were typically acquired by the university.

Table 4.4 indicates that 10 percent of the overall non-residential space is classified as classroom space that is also among the cheapest of space types at $135.24 per gsf.

Less than 1 percent of the space is classified as research which is among the most expensive of space types at $201.85 per gsf. The largest portion of the sample, comprising 30% of the overall sample is classified as Special Use. That is, athletic and physical education facilities, audio-visual facilities, non-medical clinical facilities, and demonstration facilities. These facilities had a 1995 estimated replacement value of $135.30 per gross square foot. The second largest portion of space is for offices, approximately 25% of the total with an estimated replacement value of $140 per gsf.

A fourth major characteristic of models in this study is building composition. This consists of building components such as types of windows, doors, exterior walls, roof material, and exterior trim; interior walls, windows, doors, and ceilings; piping, ductwork, light fixtures, electrical controls, wiring, and alarm systems. These components have varying lives and maintenance costs. Table 4.5 identifies a brief listing of the different components found in a single building, Coleman Hall, in the sample with corresponding recommended useful life.

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TABLE 4.5

BUILDING COMPONENTS AND RECOMMENDED LIFE FOR COLEMAN HALL

Component	% of Building	Recommended Life
Flooring	3	8 to 50 years
Windows	1	75 years
Interior Hardware	0.8	30 to 60 years
Doors	1.6	65 years
Exterior Walls	0.3	125 to 500 years
Fire Alarm Systems	1.1	20 years
Plumbing Fixtures	1.1	10 to 20 years
HVAC Equipment	58.7	15 to 20 years
HVAC Dist. Piping	1.6	30 years
Electrical Power	2.9	50 years
Electrical Lighting	2.0	20 years
Electrical Controls	0.7	30 years

The composition of a building is often the result of several factors: first cost, maintenance costs, local construction practices, architectural or engineering design preferences, and familiarity for maintenance personnel. In some cases, these factors are considered globally and conscious decisions are made during the design process to select specific building components over others based on life-cycle cost, appearance, and local construction practices. Buildings in the sample exhibit a distinct split in composition between those buildings constructed prior to 1957 and those constructed after 1957. The older buildings have stone or brick exterior walls, often load bearing walls of brick or structural clay tile, heavy interior walls, high ceilings, piped heating systems with no air-conditioning, sloped roofs, tile floors, and wood windows. The newer buildings have light exterior walls hung from a steel structure (this is typically called curtain wall construction), light interior walls, low ceilings, ducted heating and cooling systems, flat roofs, carpeted floors, and metal windows.

In summary, the sample of buildings used in this phase of data analysis contains a moderate number of buildings of varying sophistication. The sample has a replacement value of approximately $227 million and contains about 1.2 million gross square feet. The age profile indicates a moderately aged physical plant with most buildings between twenty and forty years old. The buildings are in very poor condition. Over 40% of the replacement value and gross area require renovation and renewal. Some of the buildings should be considered candidates for demolition. The older buildings are substantial structures with heavy components throughout while the younger buildings are a lightweight curtain-wall construction with easily moveable interior partitions.

4.3 Estimated Funding Need, 1953 to 1995

The first stage in the data analysis was to test the models described in Chapter 3 using the sample data and examine the results of each model. The sample used in this study is the state-supported part of the Eastern Illinois University building inventory.

This stage of the analysis examines the results of operating the various models using the sample data just described and comparing those results. Close correlation of models between each other indicates theoretical agreement. Differences may indicate errors in data, insufficient data, errors in models, or differences between the

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application of data within the models. Agreement between the individual models and the actual conditions will be analyzed later.

4.3.1 Depreciation

The first model examined in this stage of the data analysis is depreciation. Annual depreciation was determined using the straight line method recommended by Kraal (1992). There are two independent variables used by depreciation methods in order to determine an annual funding level, building age and cost.

Two sets of building cost data for the depreciation method were used, the original building cost and estimated replacement value. These data were described and determined in Chapter 3. Both sets of depreciation calculations assumed an individual building life span of fifty years. This corresponds to legislation, by the Illinois legislature, where buildings are given a life of 50 years for the purposes of bond sales that fund the construction of state university buildings. Bond sales that fund renovation of existing facilities are only given a life of 25 years. No explanation for this reasoning has been available. The process of depreciation began at the date of building construction and continued through the year 1995 or until the building reached fifty years of age, at which point it was dropped from the calculations. The depreciation calculations assumed zero salvage value for each building at the end of its life span. The nature of the depreciation calculation prevents including any building over fifty years of age in the process. The sample contains five buildings over fifty years of age. These buildings comprise approximately 4% of the total original cost of buildings, 20% of the sample replacement value, and 20% of the building area. Although they are not included in the depreciation calculation after they reach 50-years of age, they are still considered part of the inventory and require funds for operations and maintenance renovation and renewal.

The results of the SLN depreciation method using actual capital investment (original cost) and current replacement value for the sample are provided in Table 4.6 in 5-year increments. Figure 4.1 shows the depreciation-based recommendations graphically in annual amounts at 5-year intervals. The effects of inflationary changes in building replacement value become evident immediately. The use of original costs to determine depreciation-based funding estimates for major maintenance are significantly below the estimates based on current replacement value. Changes in the slope of the graph for both methods are a result of additions to the building data either resulting from the addition of a building or the loss of a building due to age.

TABLE 4.6

STRAIGHT LINE DEPRECIATION
RESULTS IN 5-YEAR INCREMENTS

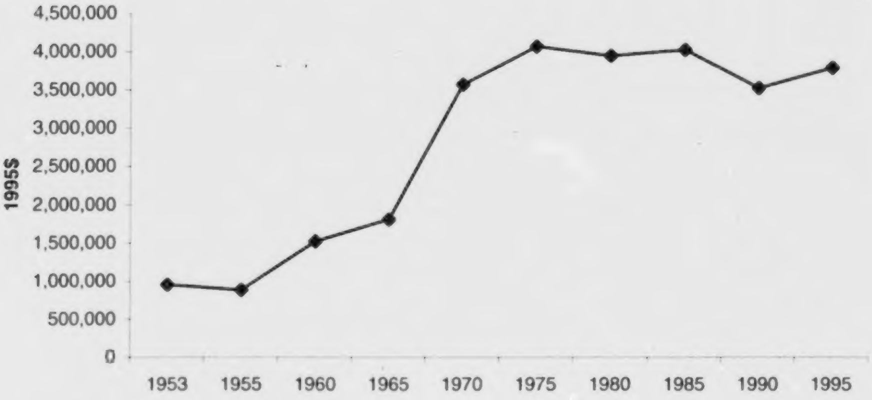
Year	Original Cost	Estimated CRV
1953	61,751	141,994
1955	63,751	139,441
1960	128,751	283,803
1965	210,265	371,284
1970	461,193	969,005
1975	583,735	1,725,536
1980	579,375	2,347,953
1985	599,375	3,142,530
1990	583,685	3,143,016
1995	725,577	3,786,440

The predicted funding needs change when buildings drop out of the depreciation analysis. The changes are better observed in a graph of replacement values in 1995 dollars. This appears in Figure 4.1. A dip in the funding recommendation between 1985 and 1995 is the result of two buildings falling out of the depreciation calculation. McAfee and Physical Science reached the age of 50 in 1987 and 1988 respectively. They represent approximately 10% of the area and replacement value in the sample.

The average annual recommended expenditure using the straight line depreciation method, with no salvage value, is 2% of CRV per year. This is within the rule of thumb range of 1.5% to 3% of CRV.

FIGURE 4.1

ANNUAL RECOMMENDED EXPENDITURES
BY DEPRECIATION MODEL 1995 DOLLARS



The graph of funding recommendations does not include any recommendations for Old Main, age 56 in 1953. Four other buildings drop out of the calculations during the analysis period. This occurs in 1961, 1977, 1987 and 1988. Between 1957 and 1972 the rapid construction of new facilities resulted in a corresponding increase in recommended facility maintenance expenditures. The removal of buildings from the calculations during the rapid growth phase of the campus is less easy to discern from the graph.

The Straight Line method is sensitive to building costs, either original value or replacement value. It generates a constant expenditure recommendation over the life of the building in constant dollars. There is no recognition of differences in maintenance needs between buildings regardless of cost. There is also no recognition of changes in maintenance costs resulting from increasing age. Expensive new buildings have a much greater effect on the overall funding prediction. The effect of a 50-year old building dropping out of the depreciation is greater when the building has a high replacement value.

4.3.2 Age Formula Funding

Sherman & Dergis (1984) describe a technique that uses building age and current replacement value to arrive at an annual funding recommendation for major maintenance The technique can also be used to modify the age of a building which has undergone significant, greater than 10% of current replacement value, renovation. This method uses a coefficient which increases at a constant rate of 1/1275 over 50 years. The reason for the constant increase in coefficient value is based on the belief that newer buildings require less maintenance than older buildings. The results of the application of the sample to this model appear in Table 4.7. This table shows the annual recommendation in five-year increments. The formula application is based on estimated replacement costs rather than original cost.

TABLE 4.7

ANNUAL AGE FORMULA FUNDING
RESULTS IN FIVE-YEAR INTERVALS
WITH ESTIMATED REPLACEMENT COSTS

Fiscal Year	**Recommended Capital Renewal Expenditure**
1953	$105,725
1955	$139,814
1960	$254,593
1965	$338,136
1970	$805,931
1975	$1,417,574
1980	$1,989,284
1985	$2,633,190
1990	$3,030,717
1995	$3,594,825

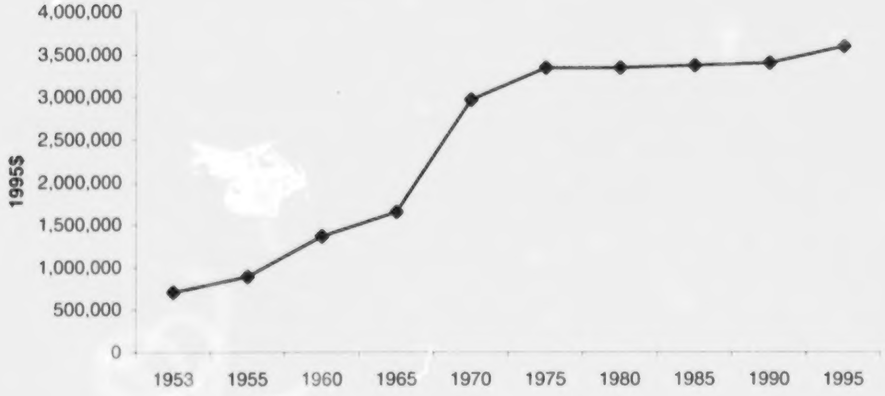
Kraal (1992) indicated, in most cases, this model estimates greater total renovation costs for individual subsystems than does a component-based model. In this sample, the age ratio model identifies higher renewal costs after the initial fifty years. It predicts lower costs than the depreciation model in early years. When the buildings have increased in age the model predicts higher costs. Regardless of whether the model predicts funding requirements better or worse than any other model it identifies a demand for funding which increases over the life of the building rather than decreasing.

A graph of the same results shown in Table 4.7 but adjusted to constant 1995 dollars in shown in Figure 4.2. This is similar to Figure 4.1 in that buildings greater than 50 years old are not included in the model. Between 1985 and 1995 a slight dip in the annual recommended funding shows that two buildings have been removed from the model. The differences lie in the annual increase, regardless of number or size of buildings, resulting from the increasing ages. The graph ends in 1995 with an upward trend reflective of the increasing average age of buildings in the sample. The effect of a 50 year old building dropping out of the model is larger than in the Straight Line Depreciation model because the factor, 50/1275, is greater than 2%.

The average annual recommended expenditure increases with the average life of the buildings in the sample. The average age of the sample in 1995 is 39 years. The average expenditure is then 38/1275 or 3% of CRV. This is higher than the straight line depreciation method and at the top of the rule of thumb range. Elimination of the buildings greater than 50 years old reduces the average age to 29 years and an average expenditure of 29/1275 or 2% of CRV.

FIGURE 4.2

ANNUAL EXPENDITURES RECOMMENDED BY AGE FORMULA MODEL, 1995 DOLLARS



Predictions for increasing funding needs based on building age correlate with the Life-Cycle Cost and Component models that consider age factors of the facility. They will be discussed further below. The relatively simple formula developed by Sherman & Dergis does not consider building use, composition, components, or maintenance levels. Since it relies solely on age and does not consider utilization of the facility, it may not be a reliable predictor of actual maintenance needs.

4.3.3 Facility Formula Funding Models

The Illinois Board of Higher Education uses a formula based on current replacement value and space utilization to identifying Capital Renewal/Deferred Maintenance funding needs. The formula funding model does not use facility age as a data element. The model uses functional academic type and a typical net assignable to gross space factor to convert the academic space into a generic construction unit. The model then applies an annually updated construction cost to determine what the annual renewal expenditures should be. This model is a recent addition to higher education in Illinois. It is based on the research of Bareither (1985).

Actual data existed as early as 1982. The sample was applied to the model for as many years as it has been in place. Additional data was generated to complete information between 1945 and 1981 utilizing historic cost data information, R. S. Means (1995). The results of the models are shown in Table 4.8. A graph of this data appears in Figure 4.3.

TABLE 4.8

FACILITY FORMULA FUNDING
MAJOR MAINTENANCE NEEDS PREDICTIONS

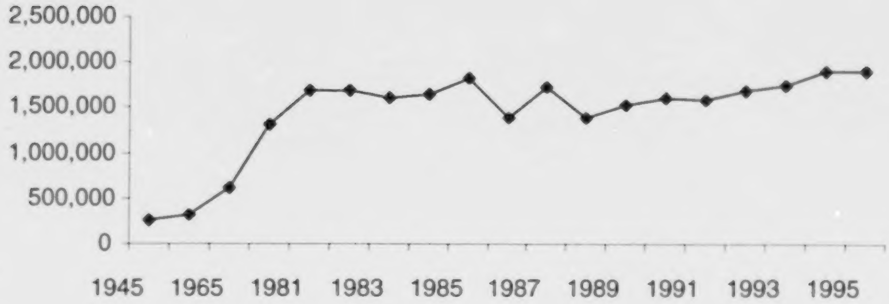
Fiscal Year	Existing Area (GSF)	Annual Need ($)
1945*	260,282	21,782
1955*	315,571	49,817
1965*	618,855	127,709
1975*	1,293,130	550,927
1981	1,367,540	1,122,539
1982	1,572,843	1,221,142
1983	1,572,843	1,221,142
1984	1,591,631	1,281,947
1985	1,591,641	1,418,900
1986	1,272,360	1,109,943
1987	1,573,620	1,429,161
1988	1,282,786	1,186,487
1989	1,314,786	1,335,494
1990	1,422,027	1,429,371
1991	1,324,600	1,456,200
1992	1,400,600	1,590,031
1993	1,414,805	1,678,574
1994	1,562,484	1,889,873
1995	1,562,577	1,906,292

* Based on estimates 1995 space assignments.

This model, similar to the straight line depreciation model, has a single coefficient of 0.67% of CRV for annual expenditures. This is significantly below the 1.5% to 3% rule of thumb. When this is modified to recognize the "commitment" of the state to completely renovate a building with separate funds within a 100-year period the average annual expenditure becomes 1.33% of CRV, still below the rule of thumb range.

FIGURE 4.3

ANNUAL EXPENDITURES BY FACILITY
FORMULA FUNDING MODEL, 1995$



Several anomalies exist in the data for this model. These occur around the years 1981 - 1988. There are several reasons why these differences arise. First, because the model was new to university planning offices in this timeframe it is assumed that details of the model were still being resolved or learned by the individuals preparing the data for submission. Misunderstandings between the IBHE and the individual universities, or differences of opinion, likely resulted in this anomalous information. An investigation by the author of data submitted to the IBHE for fiscal year 1994, with the other facility officers in the state, resulted in numerous unofficial changes in order to create comparable data for analysis in a separate effort. As an example, the model utilizes several factors that could result in large differences in the final calculated values. The incorrect classification of spaces can result in over or under estimating the value of the facility. Likewise, differences in construction cost increases for different space types will result in large changes through the gross calculations. A correction has been made in the data where an incorrect construction cost was listed and figured into the calculations in fiscal year 1986.

Second, there were inconsistencies identifying spaces that were supported with state funds. In the years 1981 through 1986, approximately 214,000 gross square feet were incorrectly recorded as state-supported. The correct value is shown in Table 4.9.

Third, the university appears to have made some changes in the fund source classification of some spaces between state-supported and auxiliary sources. There is no explanation for these minor changes in space assignments largely because the fundamental data is no longer available. There was no annual record of changes or updates. Recent changes in the management of space information have resulted in a change of maintenance habits.

The deviations from a smooth trend are not significant and can be accepted as accurate following the corrections made as described above. The resultant data is shown in Table 4.9.

TABLE 4.9

FACILITY FORMULA FUNDING MAJOR MAINTENANCE NEEDS PREDICTIONS ADJUSTED FOR BUDGETARY VARIATIONS

Fiscal Year	Existing Area (GSF)	Annual Need ($)
1945*	260,282	21,782
1955*	315,571	49,817
1965*	618,855	127,709
1975*	1,293,130	550,927
1981	1,367,540	1,122,539
1982	1,359,232	1,055,198
1983	1,359,232	1,055,198
1984	1,378,020	1,109,463
1985	1,378,030	1,227,684
1986	1,378,515	1,198,330
1987	1,360,009	1,229,832
1988	1,282,786	1,186,487
1989	1,314,786	1,335,494
1990	1,422,027	1,429,371
1991	1,324,600	1,456,200
1992	1,400,600	1,590,031
1993	1,414,805	1,678,574
1994	1,562,484	1,889,873
1995	1,562,577	1,906,292

* Estimated amounts following 1995 space assignments.

The facility formula funding model is similar to the SLN Method because it uses a specific, and constant, coefficient applied to current replacement values in recommending annual funding for renovation and renewal of buildings.

4.3.4 BRCI Model

The BRCI (Before the Roof Caves In) model developed by Biedenweg & Hudson (1980) quantifies major maintenance expenditures based on component replacement cycles and the cost of these replacements. Automation of the model was done by creating a database of components with replacement cycles and cost percentages. Table 3.12 shows the different components considered in the application of the model. The results of the BRCI analysis appear in Table 4.10.

TABLE 4.10

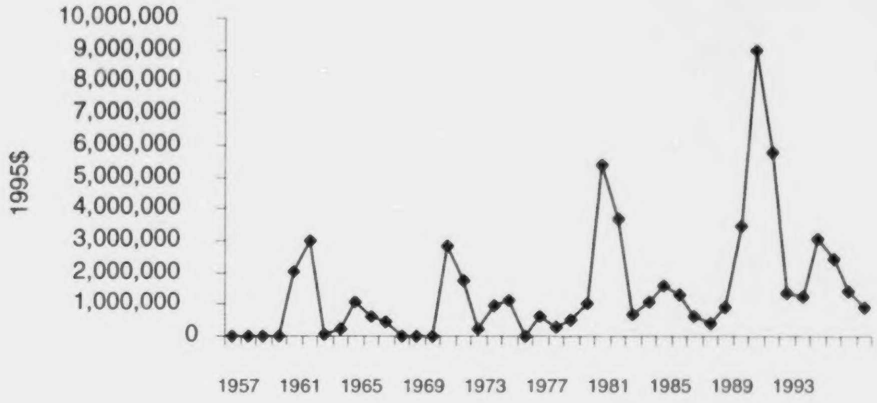
BCRI MODEL RECOMMENDATIONS FOR 1957 - 1995

Year	Annual Need ($1995)
1957	2,050,065
1958	2,966,250
1959	44,430
1960	251,123
1961	1,085,329
1962	635,794
1963	464,590
1964	0
1965	0
1966	0
1967	2,833,825
1968	1,752,672
1969	200,904
1970	988,481
1971	1,153,975
1972	0
1973	621,924
1974	255,429
1975	500,555
1976	989,745
1977	5,362,903
1978	3,670,280
1979	676,626
1980	1,051,036
1981	1,582,669
1982	1,301,845
1983	641,530
1984	384,201
1985	908,705
1986	3,425,873
1987	8,993,301
1988	5,783,462
1989	1,344,466
1990	1,247,637
1991	3,048,915
1992	2,408,557
1993	1,403,696
1994	917,446
1995	749,818

The table lists model results for all years between 1957 and 1995 because of the wide variation between years. The previous models do not exhibit similar swings. At the beginning of the period, there are five buildings in the sample. The buildings: Old Main, Blair Hall, Student Services, McAfee Gym, and Physical Science, are 58, 42, 26, 16, and 15 years old respectively. The model predicts no funding is necessary for these buildings until 1957 when $2,050,065 (1995$) is required for Student Services and McAfee Gym. There are other years where zero funding is recommended by the model, 1964, 1965, 1966, and 1972. The annual need in the intervening years ranges from a low of $44,430 to a high of $2,966,250. Figure 4.4 shows a graph of the funding recommendations.

FIGURE 4.4

GRAPH OF ANNUAL BRCI FUNDING
RECOMMENDATIONS (1953 - 1995)



The graph shows the recommended funding level ranging widely. There are eight years when no funding is recommended, and one year (1987), when almost $9 million is recommended. Biedenweg and Hudson recommended grouping costs in 5-year increments to reduce the wide variations that the model produces. They also recognize that there must be some discretion by the facility officer in management of campus buildings. Table 4.11 and Figure 4.5 show the same data grouped in 5-year intervals.

TABLE 4.11

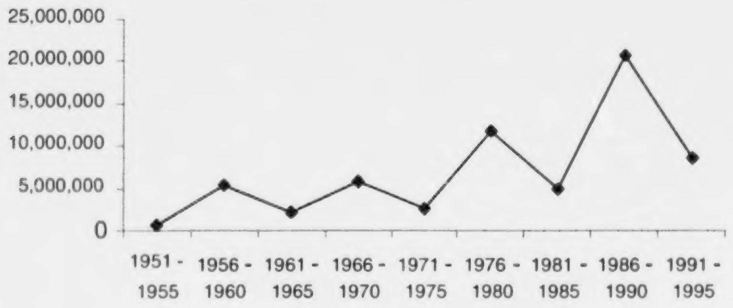
BRCI MODEL RECOMMENDATIONS
5-YEAR INTERVALS

Year	5-Year Need ($1995)
1951 - 1955	646,943
1956 - 1960	5,311,868
1961 - 1965	2,185,713
1966 - 1970	5,775,882
1971 - 1975	2,531,883
1976 - 1980	11,750,590
1981 - 1985	4,818,950
1986 - 1990	20,794,739
1991 - 1995	8,528,432

Annual funding recommendations ranged between 0.0% of current replacement value to a high of 4.04%. The wide range of expenditures is the result of concurrence between several different buildings and major maintenance efforts in those buildings.

FIGURE 4.5

GRAPH OF BRCI RECOMMENDATIONS
IN 5-YEAR INTERVALS



The average annual funding produced by this model is 0.76%, below the rule of thumb range. This is below the results obtained by Biedenweg (1997) in an updated version of his original study. This may be attributed to the author's decision to limit cumulative 50-year expenditures to 67% of CRV in order to adhere to Bareither's theory that a percentage of the facility never wears out.

4.3.5 USA-CERL

Three variations on a funding model proposed by Neely & Neathammer (1991) are studied below. The overall model is referred to as a Life-Cycle Maintenance Model (LCMM). The methods vary in complexity but are all based on a study of maintenance expenditures at several US Army installations. They all provide funding recommendations over an eighty-year period.

The US Army installation study conducted by Neely & Neathammer gathered data by investigating the maintenance costs for every component in army facilities. There was a high level of detail used to gather the data, it allowed several levels of simplification for use of the data. This study will utilize three of the data products resulting from the Army study.

The three methods to be investigated are based on varying amounts of independent data with which to apply to the methods. The first was to utilize average space costs per gross square foot based on typical building types as the independent variables. The average per gross square foot costs are identified in Table 4.12 for nine types of facilities classified by the Neely & Neathammer's study which are considered comparable to type spaces which exist in the study sample. Similar spaces were selected based on descriptive classifications provided in Appendix B of the 1991 study.

TABLE 4.12

COMPARABLE US ARMY SPACES
TO NCES SPACE TYPES

US Army Space Type	NCES Space Type
Instructional Building	Classroom
Applied Instruction Building	Laboratory
General Purpose Administration	Office
Library Facility	Study (Library)
Physical Fitness	Special Use
Auditorium/Theater	General Use
Repair and Operation Maintenance Shops	Supporting Facilities
Health Clinic	Medical Care

Table 4.13 identifies the different space types considered comparable to the replacement cost and other task tables provided by Neely & Neathammer from their studies of US Army facilities by gross square foot. Results of this analysis are performed below.

TABLE 4.13

AVERAGE MAINTENANCE COST PER SQUARE FOOT BY FACILITY TYPE (1985$)

US Army Facility Type	Annual Maintenance Cost
Instructional Building	1.51
Applied Instruction Building	1.41
General Purpose Administration	2.37
Library Facility	1.56
Physical Fitness	1.50
Auditorium/Theater	1.83
Repair and Operation Maintenance Shops	2.15
Health Clinic	2.37

As is described in the Neely & Neathammer report (1991, page 17), the study team recognized the difference between annual maintenance expenditures and major maintenance expenditures. The annual maintenance expenditures were viewed as those costs necessary to keep the building in operation but not including those costs associated with major repairs. These annual costs were referred to as Annual Recurring Maintenance (ARM). These costs are constant (exclusive of inflation) throughout the life of the building. These costs are also considered sufficient to "correct deficiencies in the original construction". The costs are identified for each facility in costs per square foot.

The major maintenance expenditures, called Major Replacement and High Cost Tasks (MRT) in the study, are those expenses necessary to replace short-lived building components or major expenditures to restore those building components on a known schedule in the building's life. These replacements are similar to the cycles identified by Biedenweg & Hudson. Table 4.14 shows the average costs per square foot, for the selected comparable space types, of the major cost tasks with the annual cost tasks removed.

TABLE 4.14

MAJOR REPLACEMENT AND
HIGH COST TASKS (MRT)
BY SQUARE FOOT (1985$)

Facility Type (US Army)	Cost per SQFT.
Instructional Building	0.79
Applied Instruction Building	0.61
General Purpose Administration	1.46
Library Facility	0.77
Physical Fitness	0.65
Auditorium/Theater	0.74
Repair and Operation Maintenance Shops	1.04
Health Clinic	1.03

The second way the LCCM was studied was to add the facility age as one of the independent variables in the model. Facility age was considered for buildings between one and 80 years old. Table 4.15 contains sample information for buildings classified for US Army facilities as administration buildings and used in this study to represent higher education office space. This table includes the timing of major repair costs through the life of the building. As an example, there are different life-cycle replacement costs for office spaces versus support spaces. This table assumes typical facility characteristics, including wall types, based on the use of the facility. No detail is provided by Neely & Neathammer regarding the typical building characteristics for the buildings analyzed in their study, so detailed clarifications about the facility characteristics can not be addressed with this method. However, more detailed information about building components and their individual life-cycle is reflected here without the associated necessary component information. Similar information for the other higher education space types appears in Tables 3.15 through 3.21.

TABLE 4.15

ANNUAL COSTS (1985$) FOR
MAJOR REPAIR AND REPLACEMENT TASKS (MRT)
FOR US ARMY GENERAL PURPOSE ADMINISTRATION BUILDINGS

	Year									
Decade	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0.000	0.000	0.010	0.050	0.050	0.020	0.090	0.240	0.370	0.150
1	0.340	0.390	0.500	0.570	0.830	0.690	0.640	0.480	0.830	0.510
2	0.600	0.470	0.510	0.450	0.800	1.040	0.910	1.030	1.000	1.150
3	1.250	1.020	1.250	0.740	0.570	0.610	0.900	0.640	0.880	1.150
4	1.050	0.490	0.470	0.500	0.550	0.380	0.400	0.490	0.770	0.470
5	0.940	0.900	0.780	0.970	1.000	0.820	1.280	1.100	1.190	1.020
6	1.190	0.900	0.910	0.910	1.180	0.690	0.960	0.890	0.880	0.960
7	1.230	1.010	1.590	1.000	1.210	1.210	0.870	0.940	1.150	1.110

The third method used in performing the Life Cycle Cost analysis is to identify specific building components through study of original building construction documents and building surveys. This will be addressed in detail later in the chapter when six buildings are closely examined.

4.3.5.1 Constant Annual Expenditures

This portion of the study utilized predicted maintenance costs for different facility types based on square footage of the facility. No adjustment is made for building age or any other building characteristics. Building area for each space type is required. This information is shown in Table 4.16 for a single fiscal year, 1988. This information is provided as an example. When the calculations were made the distribution of spaces was required in order to integrate maintenance expenditure recommendations accurately.

Table 4.16 shows the annual recommended expenditures for the sample when constant maintenance costs were used for the eight space types as shown in Table 4.14. Figure 4.6 is a graph of the results.

FIGURE 4.6

ANNUAL EXPENDITURES
USING USA-CERL CONSTANT MODEL

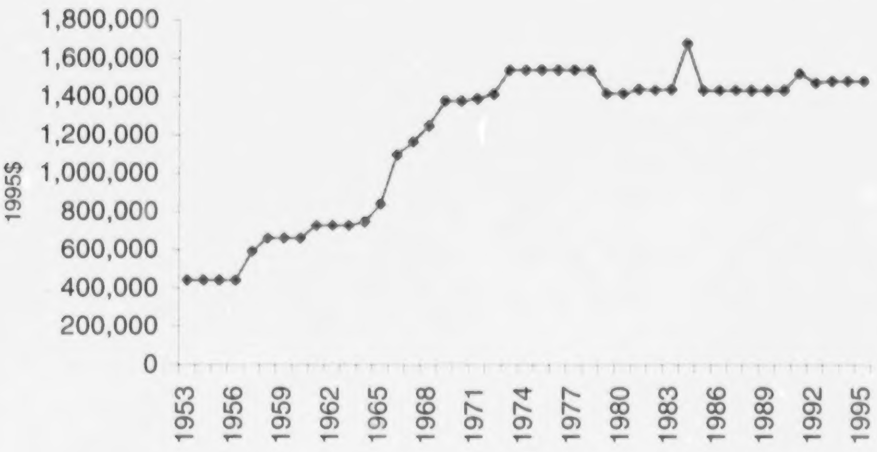


TABLE 4.16

RECOMMENDED EXPENDITURES BASED ON SPACE TYPES BETWEEN 1957 AND 1995 IN CURRENT YEAR (1995$)

Fiscal Year	Recommended Expenditure
1957	591,308
1958	660,393
1959	660,393
1960	660,393
1961	726,409
1962	726,409
1963	726,409
1964	745,584
1965	838,109
1966	1,092,675
1967	1,163,335
1968	1,248,429
1969	1,376,709
1970	1,376,709
1971	1,388,335
1972	1,412,904
1973	1,537,633
1974	1,537,633
1975	1,537,633
1976	1,537,633
1977	1,537,633
1978	1,537,633
1979	1,415,921
1980	1,415,921
1981	1,435,522
1982	1,434,314
1983	1,437,659
1984	1,676,109
1985	1,434,314
1986	1,434,314
1987	1,434,314
1988	1,434,314
1989	1,434,314
1990	1,434,314
1991	1,520,111
1992	1,473,925
1993	1,480,976
1994	1,480,976
1995	1,480,976

The total expenditures, in 1995 dollars, recommended over the 39-year period are $51,246,453. The costs generally increase over the 39-year period as buildings are added to the sample. There are two years where decreases occur. Each year, 1979 and 1992 are years when a building in the sample reaches 80 years of age and drops out of the calculations. There are no other anomalies in the recommendations because the cost per square foot by space type remains constant regardless of facility age.

The constant age life-cycle cost, by facility type, expenditure recommendations are consistently less than the depreciation methods and the formula funding model. This model is generally less than the facility formula funding model with the exceptions occurring between the years 1953 and 1975.

4.3.5.2 Major Replacement and High Cost Tasks

The recognition that buildings have different life cycle costs depending on their individual construction components and uses is more clearly demonstrated with the life-cycle cost model based on facility type area and age. An example of the input data to the model was provided in Table 4.14 with the recommendations for a general administration building. In this study the general administration building space type is considered comparable to university office space. Table 4.12 provides the listing of comparable spaces between US Army facilities and university facilities. Application of expenditure recommendations between 1953 and 1995 in 1995 dollars based on space types, building age, and square footage is shown in Table 4.17. Figure 4.7 shows this information in graphical form.

FIGURE 4.7

RECOMMENDED ANNUAL EXPENDITURES
USING USA-CERL MRT MODEL

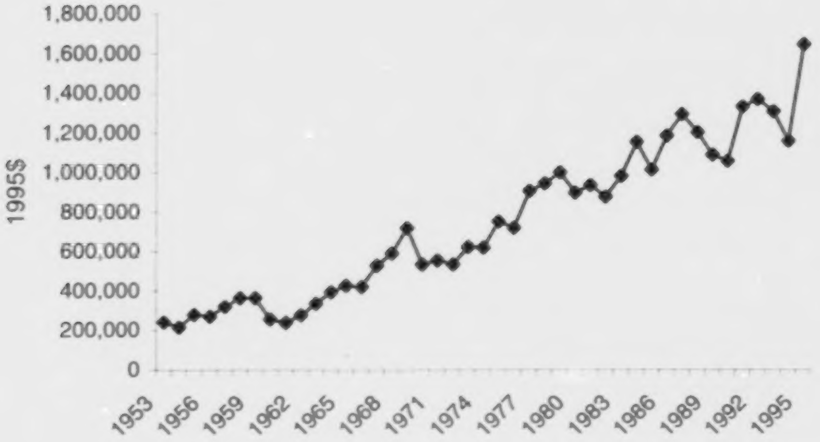


TABLE 4.17

EXPENDITURES BETWEEN 1957 AND 1995 USING MAJOR REPLACEMENT AND HIGH COST TASK (MRT) COSTS IN (1995$)

Fiscal Year	Recommended Expenditure
1957	321,750
1958	364,739
1959	364,646
1960	257,096
1961	238,830
1962	278,210
1963	334,191
1964	393,377
1965	427,036
1966	420,829
1967	527,596
1968	590,363
1969	717,880
1970	533,628
1971	553,378
1972	533,355
1973	622,255
1974	618,923
1975	749,648
1976	719,124
1977	903,388
1978	943,371
1979	999,104
1980	895,775
1981	932,662
1982	873,855
1983	981,633
1984	1,151,659
1985	1,012,998
1986	1,185,287
1987	1,291,548
1988	1,203,159
1989	1,087,279
1990	1,056,994
1991	1,331,382
1992	1,368,673
1993	1,305,698
1994	1,157,106
1995	1,646,835

Over the 39-year period the costs increase. Variations are expected because of the variations in the base data as shown in Table 4.15. Recommended expenditures increase between 1953 and 1959 and drop in 1960 and 1961. This occurs when there are eight buildings in the sample with an average age of 20 years. The oldest building is 62 years old. In most of the space types selected there is a significant reduction in the recommended expenditures for a facility between age 61 and 62. This accounts for some of the reduction observed. The largest building is only three years old and contributes very little to the total recommendation. The second largest building is 22 years old and received reductions in recommended expenditures between the twenty-first and twenty-second years. This also contributes to the reduction in total recommended expenditures.

Increases in annual recommendations resume in 1962 until 1969. The oldest building is 71 years old, the largest building is 12 years old and the average age of all buildings in the sample is 18 years old, reflective of the large increase in new buildings in the 1960's. Over 60 percent of the total space in the sample is less than ten years old and has an average recommended maintenance cost of $0.84 per square foot in 1995 dollars.

Increases in recommended expenditures resume in 1970. A 13 percent drop occurs in 1985, an 8 percent drop in 1989, and a 10 percent drop in 1994. Buildings drop out of the calculations in 1978 and 1991 when they reach eighty years in age.

The annual recommendations are all less than the other models, depreciation, formula funding, and facility formula funding. The total expenditures recommended between 1953 and 1995 are $31,905,194 versus the actual expenditures of $12,757,114. The shortfall is $19,148,080. The shortfall predicts a building condition index in 1995 of approximately 9.7, significantly less than the average condition index from the 1995 audit.

4.3.5.3 LCC Model with Combined ARM and MRT

Because terminology may vary between the military and higher education facilities officers, a separate model combining the annual recurring maintenance and major replacement and high cost tasks was studied. This combines expenditures that the US Army defines as necessary to keep the building operational with that necessary to replace short-lived components. Table 4.13 presented the ARM costs, different from the constant costs presented in Table 4.14. Model results appear in Table 4.18 and in Figure 4.8.

FIGURE 4.8

ANNUAL EXPENDITURES
USING USA-CERL ARM and MRT MODEL

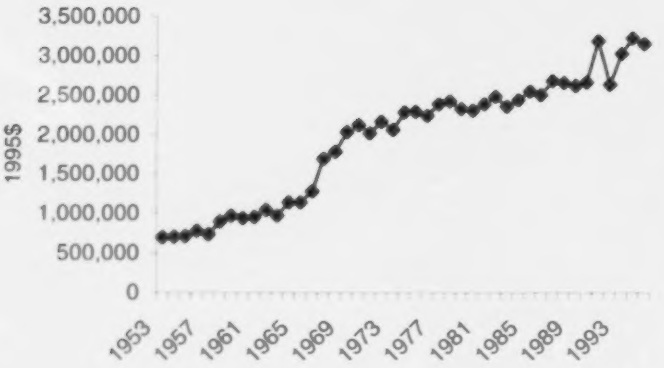


TABLE 4.18

RECOMMENDED ANNUAL EXPENDITURES USING USA-CERL ARM and MRT MODEL

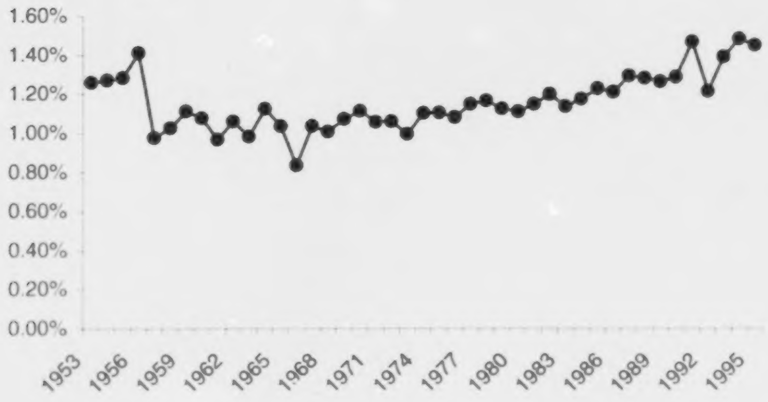
Fiscal Year	Recommended Expenditure
1957	737,150
1958	897,534
1959	971,131
1960	941,540
1961	959,879
1962	1,048,499
1963	973,749
1964	1,142,822
1965	1,139,622
1966	1,283,184
1967	1,695,971
1968	1,782,033
1969	2,036,490
1970	2,118,521
1971	2,019,708
1972	2,165,193
1973	2,065,750
1974	2,282,694
1975	2,289,974
1976	2,238,103
1977	2,384,934
1978	2,420,976
1979	2,330,516
1980	2,303,892
1981	2,384,924
1982	2,483,876
1983	2,354,788
1984	2,440,038
1985	2,549,790
1986	2,508,639
1987	2,682,147
1988	2,658,634
1989	2,619,955
1990	2,670,320
1991	3,188,159
1992	2,639,578
1993	3,024,839
1994	3,225,344
1995	3,154,224

The recommended expenditures increase approximately eight years after the building construction increases. This correlates with the increase in buildings on campus in the late 1950's and early 1960's. The recommended expenditures then increase moderately between 1975 to 1990 when the buildings have an average age of 33 years. Some cyclic behavior is shown between 1990 and 1995 and is to be expected because of the base data in the USA-CERL MRT model.

A comparison of the recommended funding levels versus replacement value of the sample results in a range of funding rates between 0.83 and 1.48% of current replacement value. This is below the rule of thumb range previously discussed. A graph of this funding ratio over time is shown in Figure 4.9.

FIGURE 4.9

RATIO OF USA-CERL ARM & MRT MODEL FUNDING VERSUS CURRENT REPLACEMENT VALUE



4.3.6 Building Condition Index

The building condition index is not a predictive model as are the previously presented models. It relies on the actual observations of building components and the overall building condition, as studied by experts, and/or people familiar with the building to identify those costs necessary to bring the building up to satisfactory condition. In the case of a group of buildings that receive regular major maintenance funding, the building condition index identifies those elements of the building which are not in satisfactory condition and the cost to correct the condition. In this sample, the buildings have not received regular major maintenance funding. They are correspondingly in unsatisfactory condition. The building condition index then becomes a measure of the amount of deferred maintenance that has accumulated over time.

Considering the amount of deferred maintenance over time in the sample, the building condition index can be used to arrive at an analogous annual funding level that can be compared to the other funding models. The sample contains an estimated level of deferred maintenance of $94,686,806 as shown in Table 4.19. The buildings in the sample have an average age of 38 years.

TABLE 4.19

DEFERRED MAINTENANCE
BY BUILDING (1995 $)

Building	Estimated Deferred Maintenance
Old Main	3,796,811
Blair Hall	2,039,354
Student Services	2,723,945
McAfee Gymnasium	9,183,176
Physical Science	4,584,472
Physical Science Addition	4,361,039
Booth Library	4,595,551
Booth Library Addition	4,864,905
Buzzard Building	12,476,124
Fine Arts Center	5,837,373
Fine Arts Addition	2,746,318
Life Science	3,970,742
Life Science Annex	718,892
Clinical Services	688,581
Coleman Hall	2,195,671
Coleman Hall Addition	3,414,566
Physical Plant	703,348
Central Stores	1,158,075
Lantz Gymnasium	13,351,850
Lantz Phase 2	5,110,350
Lantz Phase 3	497,818
Klehm Hall	3,976,781
Klehm Addition	1,512,572
Lumpkin Hall	178,492
Total	**94,686,806**

Applying the estimated deferred maintenance level against the average age of the buildings in the sample and the current replacement value results in an average annual funding recommendation of 1.15%. This amount is approximately 1/2 of the annual funding level recommended by the Straight Line Depreciation method but near the bottom of the rule of thumb range.

Because the Building Condition Index is useful to only assess the current condition of a facility and not make predictions for the future through its strict application, other methods must be developed if it is to become a predictive tool. The method may be used to identify future costs based on present conditions if one is willing to extrapolate from two or more data points over time. The implications of this will be discussed below.

4.3.7 Summary

Five predictive models were studied and applied to a sample of buildings with significant deferred maintenance. The Straight Line Depreciation and Formula Funding models predicted the greatest annual funding level. The Facility Formula Funding model predicted the least funding when strictly applied; it was in the middle when recognition of external funds were available for one half of the model application timeframe. The BRCI and USA-CERL models predicted the least average annual funding but also had selected annual funding predictions in excess of 3%, the top of the rule of thumb range.

The next section examines the accumulated deferred maintenance in the sample compared to the difference between the model predictions and actual expenditures.

4.4 Comparison of Projected Costs versus Actual Expenditures

The outcomes of the individual models were compared and analyzed from two perspectives, total funding from all sources for the 1972 to 1995 time period, and average annual cost projections for each of the models. In order to smooth out any changes between individual funding years the annual cost projections and actual budgets are viewed in five-year increments. All amounts are adjusted to 1995 dollars.

An initial assumption of no deferred maintenance existing in 1953 is made. This eliminates an estimated $15,224,091 (1995$) in accumulated expenditures as predicted by the straight line depreciation model. The Old Main building is not included at all because it is greater than 50 years old and has dropped from the depreciation model. This represents approximately 34 percent of the estimated current replacement value of five of the six buildings comprising the campus at that time.

Funding shortfalls in this study are viewed as deferred maintenance. This conforms to the definition of deferred maintenance, see 2.3.3. The estimated deferred maintenance level is compared with current replacement value of all buildings in the sample to calculate a predicted building condition value. The predicted building condition value, across the entire sample, is then compared with the actual average building condition as measured in 1987 and 1995.

4.4.1 Actual Funding

Actual funding is the amount of funds provided for renovation and renewal of the existing physical plant in a given fiscal year. Small buildings, many of them former houses, on the campus were omitted either because they represented a small percentage of the overall total or because they were acquired and generally used without any significant renovations. The period studied was 1953 to 1995. This period was selected because budget information was available. No earlier budget information was available either from the university's Budget Director or from the University Archives. Table 4.20 shows actual funding from university sources, within the university's annual budget, from 1957 to 1995. In addition, the state provided separate funding for capital projects, including repair and renovation projects, through the Illinois Capital Development Board. These major repair and renovation projects, funded between 1973 and 1995, are shown in Table 4.21. Table 4.22 shows the expenditures from all sources for buildings in the sample. No earlier major repair or renovation projects occurred according to the available records. Expenditures for new construction projects are listed in Table 4.23.

TABLE 4.20

UNIVERSITY EXPENDITURES FOR REPAIRS, RENOVATION, AND IMPROVEMENTS BETWEEN 1957 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1957	$0	$0
1958	$15,500	$87,146
1959	$20,000	$109,534
1960	$8,400	$45,070
1961	$12,000	$64,061
1962	$10,000	$52,327
1963	$26,500	$135,316
1964	$20,000	$99,717
1965	$26,000	$126,645
1966	$31,000	$144,348
1967	$34,500	$155,177
1968	$43,650	$185,293
1969	$51,750	$203,345
1970	$37,070	$136,526
1971	$26,088	$85,903
1972	$39,262	$119,253
1973	$38,250	$107,242
1974	$35,299	$90,123
1975	$52,008	$122,706
1976	$20,000	$45,075
1977	$30,700	$65,555
1978	$36,500	$72,113
1979	$43,080	$78,781
1980	$0	$0
1981	$64,800	$97,848
1982	$108,000	$150,008
1983	$111,000	$146,293
1984	$114,200	$147,207
1985	$123,500	$158,038
1986	$182,500	$229,100
1987	$170,000	$204,892
1988	$250,000	$293,938
1989	$336,900	$386,649
1990	$190,000	$212,969
1991	$83,700	$91,396
1992	$116,500	$123,884
1993	$100,000	$103,933
1994	$150,000	$151,868
1995	$100,000	$100,000

TABLE 4.21

ACTUAL EXPENDITURES WITH STATE CAPITAL FUNDS FOR REPAIRS AND RENOVATION BETWEEN 1972 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1972	$0	$0
1973	$0	$0
1974	$0	$0
1975	$1,893,502	$4,467,481
1976	$0	$0
1977	$163,500	$349,130
1978	$114,000	$225,230
1979	$1,127,990	$2,062,778
1980	$455,395	$765,266
1981	$244,984	$369,926
1982	$0	$0
1983	$0	$0
1984	$326,200	$420,480
1985	$0	$0
1986	$0	$0
1987	$0	$0
1988	$1,158,049	$1,361,577
1989	$43,911	$50,395
1990	$1,152,541	$1,291,873
1991	$76,842	$83,907
1992	$0	$0
1993	$1,060,580	$1,102,290
1994	$309,584	$313,439
1995	$193,973	$196,388

TABLE 4.22

TOTAL EXPENDITURES FROM ALL SOURCES REPAIRS, RENOVATION, AND IMPROVEMENTS BETWEEN 1957 AND 1995

Fiscal Year	Actual Expenditure	Expenditure (1995$)
1957	$0	$0
1958	$15,500	$87,146
1959	$20,000	$109,534
1960	$8,400	$45,070
1961	$12,000	$64,061
1962	$10,000	$52,327
1963	$26,500	$135,316
1964	$20,000	$99,717
1965	$26,000	$126,645
1966	$31,000	$144,348
1967	$34,500	$155,177
1968	$43,650	$185,293
1969	$51,750	$203,345
1970	$37,070	$136,526
1971	$26,088	$85,903
1972	$39,262	$119,253
1973	$38,250	$107,242
1974	$35,299	$90,123
1975	$1,945,510	$4,590,187
1976	$20,000	$45,075
1977	$194,200	$414,685
1978	$36,500	$297,343
1979	$1,483,080	$2,141,559
1980	$516,200	$765,266
1981	$309,784	$467,774
1982	$108,000	$150,008
1983	$111,000	$146,293
1984	$440,400	$567,687
1985	$123,500	$158,038
1986	$182,500	$229,100
1987	$688,203	$204,892
1988	$1,203,157	$1,655,515
1989	$336,900	$437,044
1990	$282,400	$1,504,842
1991	$365,400	$175,303
1992	$295,200	$123,884
1993	$1,160,580	$1,206,223
1994	$459,584	$465,307
1995	$293,973	$296,388

TABLE 4.23

EXPENDITURES FOR NEW FACILITIES BETWEEN 1973 AND 1995

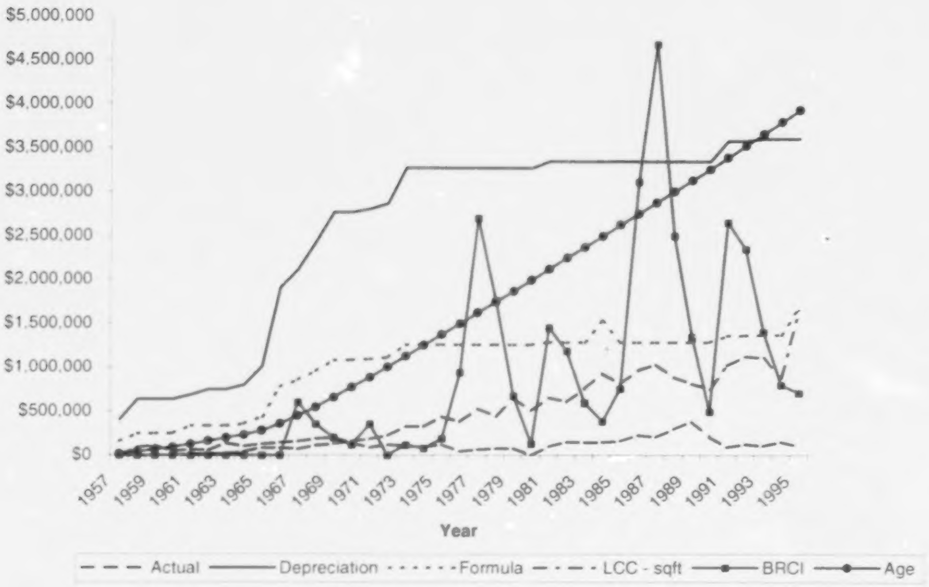
Fiscal Year	Actual Expenditure	Expenditure (1995$)
1973	$442,058	$1,239,404
1974	$393,683	$1,005,128
1975	$190,990	$450,617
1976	$0	$0
1977	$0	$0
1978	$0	$0
1979	$0	$0
1980	$0	$0
1981	$0	$0
1982	$0	$0
1983	$0	$0
1984	$0	$0
1985	$0	$0
1986	$0	$0
1987	$0	$0
1988	$0	$0
1989	$0	$0
1990	$190,725	$213,782
1991	$6,461,500	$7,055,584
1992	$0	$0
1993	$0	$0
1994	$286,472	$290,039
1995	$217,950	$217,950

The Eastern Illinois University campus experienced significant growth between 1957 and 1972 with little, if any attention paid to rehabilitation of existing space. All construction was new or dedicated to modifying existing facilities only as necessary in order to create a link to a new building or addition. This was typical of all public universities in Illinois between 1950 and 1975. It and can be observed on each of the 12 4-year campuses and the 39 2-year campuses (Aldrich, 1993). Buildings in the sample constructed between 1957 and 1972 were examined to determine the portion dedicated to CRDM as opposed to construction of new facilities.

The funding for CRDM projects in the 1957 to 1972 buildings and the funding recommended by each of the five models, is shown in Figure 4.10. A very large difference in the estimated funding needs is apparent.

FIGURE 4.10

COMPARISON OF ACTUAL EXPENDITURES
TO MODELS (1957- 1995)



4.4.1.1 Depreciation Model vs. Actual Funding

As stated by Kraal (1992), the straight line depreciation model best predicts major maintenance funding levels for young (less than 30 years old) facilities. Between 1957 and 1995, the bulk of the facilities in the depreciation model, shown in Table 4.18 were either new or young within Kraal's definition. In all years, actual funding in 1995 dollars, the difference from recommended funding was between $401,800 to $3,505,720 less than recommended. Actual funding was between 0% and 18% of recommended levels. The accumulation of funding shortfalls during this period sums to $96,576,682 in 1995 dollars. This represents approximately 55 percent of the estimated replacement value of the buildings in the sample. Restoring the ignored deferred maintenance on pre-1957 buildings, $15,224,091, yields an adjusted total funding shortfall of $111,800,773.

Investigation of the funding shortfall over the new buildings in the sample was also performed. This was done to eliminate the assumptions necessary to include the older facilities. It is also useful to consider only the new buildings when applying the model. However, it is also appropriate to apportion the annual expenditures by some method to the new and old facilities. In this case, square footage was used to develop an apportionment ratio. The ratio was then applied annually to the actual expenditure history, to develop a modified version of Table 4.22. The results of the adjusted actual expenditures and depreciation model applied to the 1957 - 1973 building sub-sample appears in Table 4.24. Then the shortfall was studied again only on the facilities constructed during the years 1957 to 1972, inclusive.

TABLE 4.24

1957 - 1973 BUILDINGS WITH DEPRECIATION MODEL PREDICTIONS AND ACTUAL EXPENDITURES FOR MAJOR MAINTENANCE

Fiscal Year	SLN Prediction	Actual
1957	$401,620	$0
1958	$638,153	$22,349
1959	$639,085	$41,519
1960	$636,373	$17,084
1961	$684,877	$24,284
1962	$746,880	$22,893
1963	$747,922	$59,197
1964	$800,019	$43,621
1965	$1,010,409	$57,317
1966	$1,906,460	$71,797
1967	$2,106,731	$97,217
1968	$2,433,469	$121,449
1969	$2,757,898	$140,039
1970	$2,768,106	$94,784
1971	$2,800,678	$59,640
1972	$2,862,626	$83,187
1973	$3,273,428	$74,809
1974	$3,273,118	$64,040
1975	$3,271,627	$87,195
1976	$3,272,549	$32,030
1977	$3,268,259	$46,583
1978	$3,269,477	$51,244
1979	$3,271,413	$55,983
1980	$3,269,958	$0
1981	$3,269,158	$68,577
1982	$3,270,572	$105,126
1983	$3,267,162	$102,524
1984	$3,267,110	$103,163
1985	$3,272,673	$110,755
1986	$3,272,067	$160,555
1987	$3,271,556	$143,589
1988	$3,268,399	$205,994
1989	$3,272,900	$270,966
1990	$3,269,859	$149,250
1991	$3,271,116	$64,051
1992	$3,272,495	$82,109
1993	$3,269,866	$68,886
1994	$3,271,390	$100,656
1995	$3,270,400	$66,279

The result of this variation in the study of the depreciation model against actual expenditures resulted in a shortfall of $95,997,120 (1995$) of expenditures representing an average building condition index of 50.6 for the buildings constructed between 1957 and 1973. This compares with an average index for these buildings of 44.9.

Over the forty-three year period, the overall funding shortfall between actual funding level and the straight line depreciation model is $118 million. In other words, funding was about 10% of the recommended level. The percentage of funding shortfall has trended down in recent years but is still large relative to the recommendation. In terms of the building condition audit, the campus should average a condition code 12. Looking at the funding shortfall between 1957 and 1987, the end year chosen because of the building condition audit performed during that fiscal year, resulted in a total shortfall of $49 million or 92% of the recommended level. The average condition code should be 27. Comparison with the average condition code determined in these two years results in a difference of 6.9 and 26.1 or 20% and 69% respectively.

4.4.1.2 Age Model vs. Actual Funding

A similar comparison between the Sherman & Dergis (Age) model and the actual expenditures was performed. The model uses facility age and replacement cost as the independent variables necessary to determine the annual funding requirements for major maintenance. The model predicts a cumulative expenditure shortfall of $58,585,900 over the thirty-eight year period. This is less than the predicted expenditures by the straight line depreciation model. The funding shortfalls result in a predicted building condition index of 33.1.

Examining those buildings constructed between 1957 and 1991 produced different results. This trial eliminates the effects of the older buildings in the sample. It is consistent with observations made by Kraal wherein he observes that the model produces favorable results when it is applied to buildings of similar construction type and use. All the buildings in this sample consist of steel frame construction with a light curtain wall construction. They are all primarily classroom facilities with some special laboratories. In this case, the youngest buildings in the sample are included because of Kraal's observation. A second sub-sample of just the 1957 to 1973 buildings was examined for consistency with the depreciation model. Comparison of these resulted in a difference of less than one percent.

The newer buildings had a recommended total expenditure for major maintenance between 1957 and 1995 of $63,515,178 dollars. The shortfall in funding resulting from the expenditures over the same period is $56,280,793. The corresponding predicted building condition index is 31.8 compared to the observed building condition index of 44.6. This is an understatement of the wear on the buildings of 12.8 percent.

4.4.1.3 Facility Formula Funding Model vs. Actual Funding

A comparison of actual funding against the formula model appears in Table 4.25. The Illinois Board of Higher Education formula resulted in annual shortfalls between \$19,365 and \$1,607,728 or 0% and 92.2% of recommended levels. The cumulative recommended spending for years ending 1989 and 1995 is \$29.0 million and \$40.0 million with accumulated shortfalls of \$22.9 million and \$32.8 million respectively. The resultant funding shortfalls predict average building conditions of 12.9 and 18.5. These shortfalls are considerably smaller than those of the depreciation method because of the smaller percentage factors that are used against current replacement value estimates to set the annual recommendation for funding.

TABLE 4.25

SHORTFALL IN FUNDING BETWEEN ACTUAL EXPENDITURES AND FORMULA FUNDING RECOMMENDATION

Fiscal Year	Shortfall (1995$)
1957	$154,565
1958	$121,098
1959	$19,365
1960	$155,088
1961	$206,092
1962	$215,938
1963	$33,453
1964	$137,606
1965	$158,195
1966	$441,934
1967	$418,427
1968	$442,147
1969	$533,065
1970	$734,247
1971	$896,597
1972	$860,661
1973	$1,050,987
1974	$1,097,227
1975	$1,055,004
1976	$1,188,543
1977	$1,161,259
1978	$1,159,487
1979	$1,158,353
1980	$1,260,730
1981	$1,184,656
1982	$1,140,507
1983	$1,154,746
1984	$1,395,339
1985	$1,144,794
1986	$1,084,971
1987	$1,113,463
1988	$1,044,325
1989	$975,544
1990	$1,119,230
1991	$1,288,822
1992	$1,271,449
1993	$1,299,087
1994	$1,268,773
1995	$1,607,728

4.4.1.4 Biedenweg & Hudson (BRCI) Model vs. Actual Funding

The shortfall between BRCI model predictions for the 1957 to 1995 period and actual expenditures appear in Table 4.26. This model presented results that are not typical of the straight formulaic methods. The first ten years have no recommended expenditures for major maintenance. The "shortfall" in the first ten years is an excess, this offsets the accumulation of deferred maintenance in subsequent years from an accounting basis. As more of the new buildings are constructed and included in the model, the recommended expenditures increase. The model predicts $349,361 less to $4,510,305 more than was actually spent. This wide range of spending recommendations is a result of the cyclic nature of the model.

Because there are excess expenditures for major maintenance to the new buildings the predicted accumulation of deferred maintenance is much lower than with the other methods. Estimated BCI in 1987 is 8.1. The estimated BCI in 1995 is 14.3. These estimates are significantly below the observed BCI in both years. The assumption to distribute spending that was not clearly documented may be incorrect. This will be discussed further in Chapter 5.

TABLE 4.26

SHORTFALL IN FUNDING BETWEEN ACTUAL EXPENDITURES AND BRCI MODEL RECOMMENDATIONS

Fiscal Year	Shortfall (1995$)
1957	$0
1958	-$125,654
1959	-$227,386
1960	-$91,664
1961	-$129,637
1962	-$119,792
1963	-$302,276
1964	-$217,488
1965	-$279,189
1966	-$334,315
1967	$165,441
1968	-$161,769
1969	-$349,361
1970	-$231,156
1971	$157,843
1972	-$252,669
1973	-$91,667
1974	-$86,994
1975	-$18,062
1976	$873,128
1977	$2,595,693
1978	$1,657,457
1979	$574,249
1980	$130,252
1981	$1,345,838
1982	$1,038,643
1983	$461,977
1984	$251,221
1985	$614,684
1986	$2,912,110
1987	$4,510,305
1988	$2,252,765
1989	$1,033,488
1990	$326,975
1991	$2,579,102
1992	$2,259,477
1993	$1,332,101
1994	$698,352
1995	$639,108

4.4.1.5 Building Condition vs. Actual Funding

A Building Condition Index (BCI) is developed following observation of building components over time and after the fact. The four previous models predict funding needs based on initial building information. In order to utilize the BCI to make similar comparisons of funding it is necessary to establish a baseline, by performing a building audit and establish an index, then conduct another audit after several years.

This was done by performing a building condition survey in 1987 to establish the baseline. After eight years another study was performed to establish a new condition index. The difference between the two studies can be compared against the actual expenditures in the intervening time and used to predict what the 1995 building conditions should be.

The 1987 survey identified numerous building problems. The average building condition index was 27.4. The replacement value of the buildings surveyed in 1987 was $146,151,433 (1995$). This resulted in an estimated deferred maintenance backlog of $50,467,622 (1995$). In 1995, the backlog is $67,160,532, a BCI of 34.5. There is a net increase of deferred maintenance of $16,305,449. Expenditures from all sources for major maintenance from 1987 to 1995 are shown in Table 4.27.

TABLE 4.27

EXPENDITURES FOR DEFERRED MAINTENANCE
1987 to 1995 in (1995$)

Fiscal Year	Expenditure
1987	$829,453
1988	$1,414,613
1989	$386,649
1990	$316,540
1991	$398,996
1992	$313,910
1993	$1,502,353
1994	$1,476,459
1995	$712,000

Total expenditures for major maintenance was $7,350,972. This is $43.1 million less than was predicted as being required to restore the campus facilities in 1987 to like new condition. The corresponding building condition index becomes 29.5. The actual building condition survey of 1995 identified an average building condition index of 33.3, a difference of 3.8 or 13%.

The difference can be reduced assuming the buildings continued to worsen faster each year. Then 13% is approximately equal to a rate of 1.5% each year. The difference may be accounted in a difference between evaluators or individual opinions between the two surveys. In addition, some conditions can be made either better or worse depending on the level of annual expenditures for corrective maintenance as proposed by Kaiser (1995).

4.4.1.6 Summary

The differences in funding between predictions of a model and the actual expenditures should appear in results of the building audits. This is shown to be the case over a given time period. There is not close agreement between the results predicted by the different methods, which was assumed. Different methods are used for different reasons, including the mix of the building inventory requiring major maintenance expenditures as was discussed by Kraal (1992). The apparent accuracy of the building condition index as a tool to identify needed expenditures indicates its usefulness for comparison of other models. These differences will be discussed in more detail in Chapter 5.

The BCI method appeared to be the most accurate method for determining deferred maintenance funding. It was followed by the Age, Depreciation, Formula, and BRCI methods in order. The Age Model was the most accurate method but still resulted in a difference of 12.8 percent of total CRV or an error of 29%. This is a very large error, even when one recognizes that predicting the future is extremely difficult.

4.5 Cyclical Models

The third step in the analysis is to review cyclical methods. These are often used in performing the Life Cycle Cost analysis in order to do value engineering on a project while it is still in design. The cyclical methods studied are: Biedenweg & Hudson (BRCI) model, the USA-CERL square footage based models, and the USA-CERL LCC model that requires specific and detailed building information. Data from ASTM Document E917 was used to develop the last model. It details costs based on time, material, and equipment usage following the methods described by Neely & Neathammer. Actual hourly costs for different trades were determined from historic records and applied on an annual basis. The previous two methods are applied as has been previously demonstrated and then compared with the detailed analysis.

The lack of information available from university records required a sub-sample be identified. Six buildings were selected for application of the building component life cycle cost model. The selected buildings were: the Fine Arts Center, constructed in 1958 and a 1972 addition; the Life Science Building and Annex, constructed in 1961; Coleman Hall and addition, constructed in 1965 and 1968; Klehm Hall and addition, constructed in 1967 and 1969; Physical Plant buildings, constructed in 1965, and 1972; and the Lantz Gymnasium and Fieldhouse complex, constructed in 1965 and 1972. These buildings were selected as being reflective of the types of facilities on campus. The combined buildings contain all the building space types typical of a college or university, although not necessarily in a particular distribution.

The six buildings selected were all constructed during the heavy building period at Eastern Illinois University. They all exhibit the typical construction techniques used during that period. These include steel frame construction with light exterior walls, often glass in steel sash. Single wythe brick or light weight stone and some precast concrete panels are the typical solid elements in exterior building walls. Interior corridor walls consist of exposed and finished brick and some painted concrete block elements that provide a hard-wearing surface. Floors are typically vinyl tile with few unfinished concrete floors, even in laboratory spaces. Ceilings are present in nearly every space and are typically concealed spline. This ceiling type limits access to ceiling-mounted equipment more than no ceiling but less than a plaster ceiling.

Office and classroom walls are comprised of wallboard on metal studs with some insulation to attenuate sound transmission. Doors are typically glass and steel at exteriors and either wood or metal at interior locations.

The mechanical and electrical systems vary the most between the buildings. Buildings with a large percentage of classrooms and offices, are air-conditioned, others are not. Perimeter radiation is typical with the light exterior wall construction. Centrally delivered conditioned-air provides make-up heat in the winter and cooling in the summer. Temperature control systems were originally a centrally controlled pneumatic system with thermostats in a few locations on each floor of the building. Improvements made in the late '80s and early '90s to control energy consumption converted the temperature controls from pneumatic to direct digital controls, DDC. Some additional thermostats were added at the time. Electrical systems consist of lighting specific to the facility use, with incandescent light primarily as a decorative element. Two-wire service in the pre-1967 buildings has been upgraded selectively to three-wire service to accommodate the electrical needs of personal computers. Fire alarm systems were limited to pull stations and enunciators (horns or bells) and few sensors. Again, these have been upgraded as a result of changes mandated by the state.

Building construction documents were studied to determine all the necessary inputs to the USA-CERL LCC method. A list of building components and quantities was created for each building that were comparable to described building components in the Building Maintenance, Repair, and Replacement Database (BMDB) for Life-Cycle Cost Analysis, (ASTM, 1991). Each list was then analyzed with the appropriate cycle and cost information for the area. The results of each annual analysis were then studied in three ways with the other cyclic methods.

4.5.1 BRCI Model

The Biedenweg & Hudson BRCI model, previously used on the entire sample, was used to study the six selected buildings. The same parameters that were previously used, Table 3.12, are applied. The results are shown in Table 4.28. Recommended expenditures for the first full fiscal year of occupancy and all subsequent years are shown.

TABLE 4.28

BRCI ANALYSIS FOR SELECTED BUILDINGS IN SAMPLE
OVER ONE HUNDRED YEARS
(1995$)

Age	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
10	$472,211	$353,780	$425,532	$1,362,806	$354,228	$106,509
12	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
20	$1,416,633	$1,061,341	$1,276,594	$4,088,418	$1,062,685	$319,526
24	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
25	$472,211	$353,780	$425,532	$1,362,806	$354,228	$106,509
30	$1,731,442	$1,297,194	$1,560,281	$4,996,955	$1,298,837	$390,532
36	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
40	$1,416,633	$1,061,341	$1,276,594	$4,088,418	$1,062,685	$319,526
48	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
50	$3,305,479	$2,476,461	$2,978,718	$9,539,642	$2,479,598	$745,561
60	$2,833,268	$2,122,681	$2,553,188	$8,176,836	$2,125,369	$639,052
65	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
70	$472,211	$353,780	$425,532	$1,362,806	$354,228	$106,509
72	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
75	$472,211	$353,780	$425,532	$1,362,806	$354,228	$106,509
80	$1,416,633	$1,061,341	$1,276,594	$4,088,418	$1,062,685	$319,526
84	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
90	$1,731,442	$1,297,194	$1,560,281	$4,996,955	$1,298,837	$390,532
96	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
100	$4,249,901	$3,184,022	$3,829,782	$12,265,254	$3,188,055	$958,578

The results of the BRCI model demonstrate there are a large number of years when no major maintenance expenditure is anticipated for any single building. The developers of the model suggest that the recommended expenditures be viewed in 5-year increments to avoid wide swings in funding and to allow for some independent judgement on the part of the facility officer. The funding recommendations in this form appear in Table 4.29 and in Figure 4.11.

TABLE 4.29

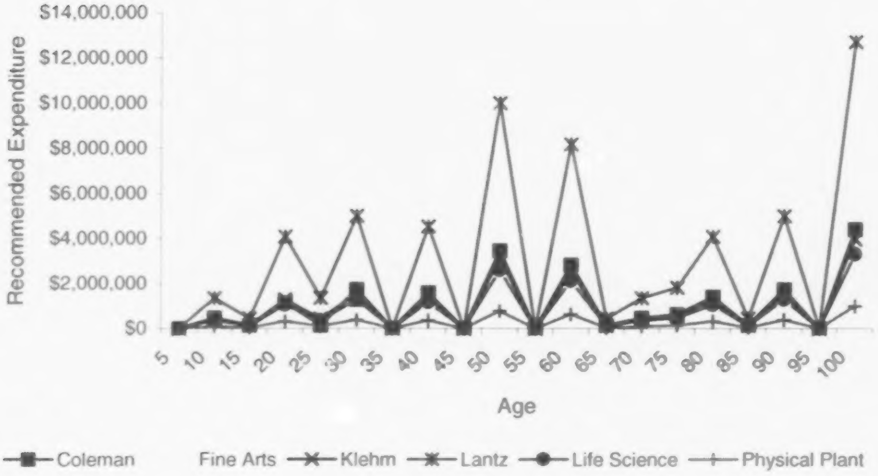
BRCI ANALYSIS FOR SELECTED BUILDINGS, 5-YEAR INTERVALS

(1995$)

Age	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
5	$0	$0	$0	$0	$0	$0
10	$472,211	$353,780	$425,532	$1,362,806	$354,228	$106,509
15	$157,404	$117,029	$141,844	$454,269	$118,076	$35,503
20	$1,146,633	$1,061,341	$1,276,594	$4,088,418	$1,062,685	$319,526
25	$157,404	$353,780	$425,532	$1,362,806	$354,228	$106,509
30	$1,731,442	$1,297,194	$1,560,281	$4,996,955	$1,298,837	$390,532
35	$0	$0	$0	$0	$0	$0
40	$1,584,037	$1,179,268	$1,438,438	$4,542,687	$1,180,761	$355,029
45	$0	$0	$0	$0	$0	$0
50	$3,462,883	$2,594,388	$3,140,562	$9,993,911	$2,597,674	$781,064
55	$0	$0	$0	$0	$0	$0
60	$2,833,268	$2,122,681	$2,553,188	$8,176,836	$2,125,369	$639,052
65	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
70	$472,211	$353,780	$425,523	$1,362,806	$354,228	$106,509
75	$629,615	$471,707	$567,376	$1,817,075	$472,304	$142,012
80	$1,416,663	$1,061,341	$1,276,594	$4,088,418	$1,062,685	$319,528
85	$157,404	$117,927	$141,844	$454,269	$118,076	$35,503
90	$1,731,442	$1,297,194	$1,560,281	$4,996,955	$1,298,837	$390,532
95	$0	$0	$0	$0	$0	$0
100	$4,407,305	$3,301,949	$3,971,626	$12,719,523	$3,306,131	$994,081

FIGURE 4.11

BRCI ANALYSIS FOR SELECTED BUILDINGS IN SAMPLE, 5-YEAR INTERVALS



Large swings in the recommended funding for major maintenance are seen in all six facilities over the study period. This is more clearly shown when these costs are normalized in terms of expenditure per square foot. When this is done the expenditure recommendation becomes as shown in Table 4.30.

TABLE 4.30

BRCI ANALYSIS FOR SELECTED BUILDINGS, 5-YEAR INTERVALS, COST PER SQUARE FOOT

(1995$)

Age	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
5	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10	$5.09	$5.39	$5.26	$4.93	$5.60	$6.27
15	$1.70	$1.78	$1.75	$1.64	$1.87	$2.09
20	$12.36	$16.16	$15.78	$14.78	$16.80	$18.82
25	$1.70	$5.39	$5.26	$4.93	$5.60	$6.27
30	$18.67	$19.76	$19.29	$18.06	$20.53	$23.00
35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
40	$17.08	$17.96	$17.78	$16.42	$18.67	$20.91
45	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
50	$37.33	$39.51	$38.82	$36.12	$41.07	$46.00
55	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
60	$30.54	$32.33	$31.56	$29.55	$33.60	$37.64
65	$1.70	$1.80	$1.75	$1.64	$1.87	$2.09
70	$5.09	$5.39	$5.26	$4.93	$5.60	$6.27
75	$6.79	$7.18	$7.01	$6.57	$7.47	$8.36
80	$15.27	$16.16	$15.78	$14.78	$16.80	$18.82
85	$1.70	$1.80	$1.75	$1.64	$1.87	$2.09
90	$18.67	$19.76	$19.26	$18.06	$20.53	$23.00
95	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
100	$47.51	$50.29	$49.09	$45.97	$52.27	$58.55

The costs for major maintenance of buildings following the BRCI model increases over time until a consistent level is reached. There are some variations in the recommended 5-year expenditures due to the different periodicity of the individual replacement cycles. When the model is applied to a mix of buildings constructed in different years the periodicity is less pronounced. Tables 4.31 and 4.32 show how the BRCI analysis applies to the sample when construction dates are included.

Expenditures for major maintenance range between 0 and 28% of current replacement value. The average recommended expenditure, every five years, is 6.7% for the buildings or 1.34% per year. This average is less than the predicted level by Biedenweg (1997) which is 1.5% of CRV. This is due to the selection of replacement values for building components for this model application as described in Chapter 3. The average annual expenditure can be increased by increasing the frequency of replacement cycles for the components considered, by increasing the estimated cost for component replacement, or by increasing the percentage of building components which require periodic major maintenance.

TABLE 4.31

BRCI ANALYSIS FOR SELECTED BUILDINGS
APPLIED TO CONSTRUCTION DATES, 5-YEAR INTERVALS
(1995$)

Year	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
1965	-	$0	-	-	$0	-
1970	$0	$471,707	$0	$0	$0	$0
1975	$187,664	$0	$0	$0	$472,304	$0
1980	$347,102	$1,061,341	$528,291	$1,747,934	$0	$142,012
1985	$657,841	$471,707	$39,085	$69,141	$1,180,761	$108,632
1990	$1,103,860	$1,297,194	$1,276,594	$4,197,768	$354,228	$355,029
1995	$1,047,498	$117,927	$597,376	$1,655,869	$1,298,837	$386,434

TABLE 4.32

BRCI ANALYSIS FOR SELECTED BUILDINGS
PERCENT OF CRV, 5-YEAR INTERVALS

Year	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
1965	-	0	-	-	0	-
1970	0	4.41	0	0	0	0
1975	1.01	0	0	0	4.80	0
1980	1.87	9.91	3.93	5.13	0	2.55
1985	3.54	4.41	0.29	0.20	12.01	1.72
1990	5.94	12.12	9.49	12.31	3.60	5.63
1995	5.64	1.10	4.44	4.86	13.21	6.13

FIGURE 4.12

BRCI ANALYSIS FOR SELECTED BUILDINGS IN SAMPLE, 5-YEAR INTERVALS, PERCENT OF CRV

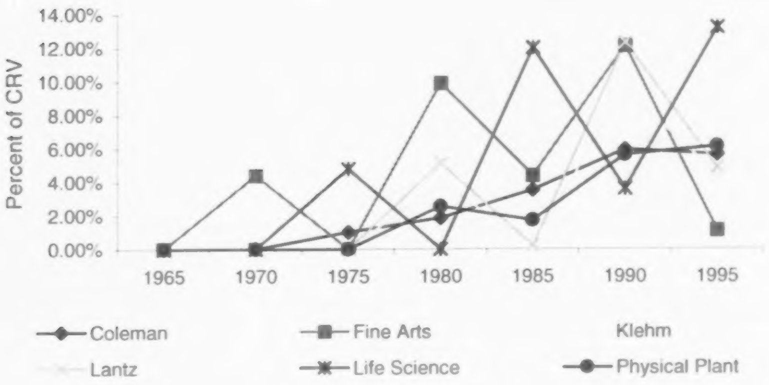


Table 4.33 shows the predicted building condition index (BCI) had the BRCI method been used to fund major maintenance for the six buildings. The table shows the recommended expenditure in 1995 dollars required for each building's life. It also shows the BCI which would result had the expenditures been made and the actual BCI.

TABLE 4.33

PREDICTED BUILDING CONDITION INDEX USING THE BRCI MODEL FOR MAINTENANCE EXPENDITURE RECOMMENDATIONS THROUGH THE YEAR 1995 (1995$)

Building	BRCI Expenditure Recommendation	Predicted Building Condition Index	Actual Building Condition Index
Fine Arts	$3,419,876	22.8	49.0
Life Science	$3,306,130	27.2	42.8
Coleman Hall	$3,343,965	18.1	39.6
Klehm Hall	$2,441,346	14.2	43.0
Lantz Gym	$7,670,712	17.0	48.0
Physical Plant	$992,107	27.4	34.2

There is a large difference between the predicted and the actual building condition indices for all the buildings examined. The least difference occurs with the Physical Plant. The greatest difference occurs with Lantz Gym. This indicates that the BRCI method under-predicts the funding needs for major maintenance.

4.5.2 USA-CERL Square Foot Model

The Neely & Neathammer model based on costs per square foot produces similar results. Application of this model to the six-building data set produces results as shown in Table 4.34 and Figure 4.13. These have been summed and reduced to five-year intervals to allow easier comparison to Table 4.32 and Figure 4.12 above.

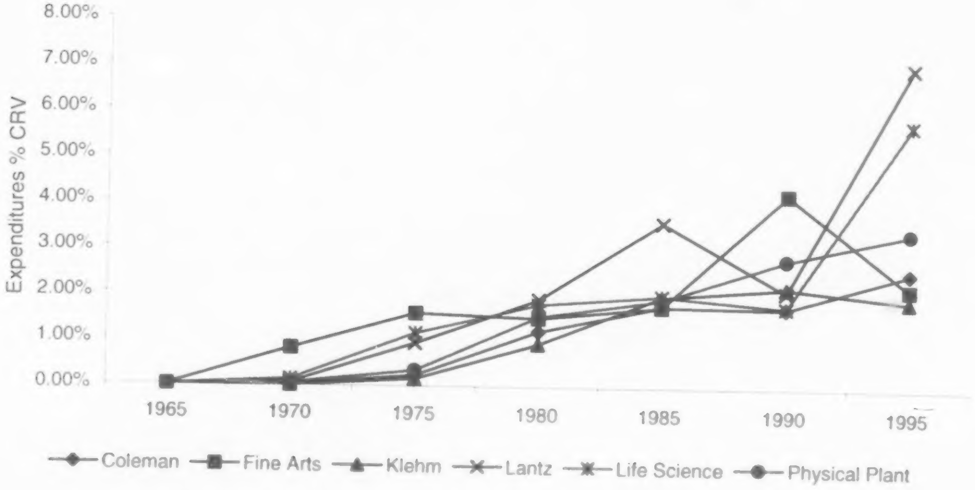
TABLE 4.34

USA-CERL ANALYSIS FOR SELECTED BUILDINGS IN SAMPLE, 5-YEAR INTERVALS, PERCENT OF CRV

Year	Coleman	Fine Arts	Klehm	Lantz	Life Science	Physical Plant
1965	-	0	-	-	0	-
1970	0.02	0.81	0	0.06	0.13	0.05
1975	0.23	1.58	0.16	0.93	1.15	0.34
1980	1.21	1.50	0.93	1.90	1.79	1.53
1985	1.77	1.76	1.98	3.59	2.00	1.91
1990	1.74	4.22	2.19	2.10	1.77	2.79
1995	2.53	2.18	1.91	7.01	5.75	3.39

FIGURE 4.13

USA-CERL ANALYSIS FOR SELECTED BUILDINGS IN SAMPLE, 5-YEAR INTERVALS, COST PER SQUARE FOOT



Total costs for each of these buildings can be compared to the building condition index (BCI). Comparison is made with the total recommended expenditures by the

USA-CERL square foot method, less actual expenditures, and the measured index. Table 4.35 shows the results of this comparison.

TABLE 4.35

PREDICTED BUILDING CONDITION INDEX USING USA-CERL SQUARE FOOT MAINTENANCE EXPENDITURE RECOMMENDATIONS THROUGH THE YEAR 1995 (1995$)

Building	USA-CERL Expenditure Recommendation	Predicted Building Condition Index	1995 Building Condition Index
Fine Arts	$5,731,227	30.6	49.0
Life Science	$3,822,679	56.9	42.8
Coleman Hall	$4,814,754	6.1	39.6
Klehm Hall	$3,567,230	25.5	43.0
Lantz Gym	$16,060,608	47.1	48.0
Physical Plant	$1,257,071	44.0	34.2

There are differences on both the positive and negative side between the predicted BCI following the USA-CERL expenditure recommendations for major maintenance and the measured BCI. The USA-CERL method most closely predicts the BCI at Lantz Gymnasium it is within 2% of the observed condition. It is least accurate with Coleman Hall with an error of 85%. In one case it over predicts the maintenance needs, at Physical Plant the error is 29% high. This indicates that the USA-CERL model, when sufficiently matched to higher education space types may prove to be a sufficiently accurate means of predicting major maintenance expenditures.

4.5.3 LCC Model with Building Components

The most detailed method developed by Neely & Neathammer, and requiring the greatest amount of building data, utilizes specific building component information in order to determine annual expenditures. Use of this model required investigation of historic building information as well as detailed examination of buildings in place. The historic information available from EIU Physical Plant records is insufficient. Drawings were either unavailable or contained numerous errors or omissions as determined by field observation. Several renovations occurred throughout the life of the university where no record drawings were made. The older buildings, pre-1990's, do not have accurate records of original conditions or of subsequent renovations. In facilities where there were no renovations over the building life differences still exist between university records and field observations. Many of these differences can be attributed to poor administration of university property when the university did not obtain as-built, record, drawings of the facilities following construction.

Shortcomings in management of the campus facilities, or a lack of sophistication, then led to the next data gap. The quantity and type of materials and equipment are also unknown because the university did not have material take-off records from the contractors. This information is typically obtained when a building is constructed through contractor records and must be estimated after the project is complete if not previously obtained. All these information shortcomings make implementation of the building component life-cycle cost model difficult when done after the fact.

A review of university records indicated that building specifications varied greatly in quality and detail over time. The first buildings in the sample were constructed at a time when local area practices governed the type of building design and composition. The youngest buildings in the sample reflect more designer-specified characteristics which then govern the material and equipment make-up but which were installed following local practices. In the oldest buildings, no specifications were available while in others only vague references were made to material types. During the building boom at Eastern, specifications had increasing detail for each building constructed. A summary of the types and life cycles of components found in the six buildings appears in Table 4.36.

TABLE 4.36

TYPICAL BUILDING COMPONENTS WITH LIFE-CYCLE TERMS

Component Description	Units Measured	Replacement Life
Roof Covering, built-up roofing	SF	28
Roof Covering, modified bitumen	SF	20
Roof Covering, concrete sealed poured	SF	500
Exterior Finish, clay brick	SF	500
Exterior Finish, alum. siding anodized	SF	100
Exterior Finish, Formica-vinyl	SF	40
Exterior Doors, aluminum (plain/anod.)	CT	65
Exterior Doors, steel (painted)	CT	80
Exterior Doors, solid wood (painted)	CT	40
Interior Doors, steel (painted)	CT	80
Interior Doors, aluminum (plain/anod.)	CT	65
Interior Doors, solid wood (painted)	CT	40
Wall Finishes, concrete block (painted)	SF	500
Wall Finishes, plate glass	SF	200
Wall Finishes, sheetrock	SF	300
Flooring, ceramic tile	SF	50
Flooring, carpet	SF	8
Flooring, vinyl tile	SF	18
Ceilings, sheetrock	SF	300
Ceilings, acoustic tile	SF	65
Plumbing, W & V, pipe & fittings, CI	TF	40
Plumbing, W & V, pipe & fittings, PVC	TF	25
Hot Water, Pipe/Fittings, steel/iron	TF	75
Hot Water, Pipe/Fittings, copper	TF	25
Cooling, chiller water cooled recip 100T	CT	20
Cooling, one stage absorption 100T	CT	20
Lighting, incandescent fixture	CT	20
Lighting, fluorescent	CT	20

Table 4.36 uses units. SF, square feet; CT, count or individual item; or TF, thousand linear feet. These units are applied in a database to reach an estimate of the maintenance costs for a building.

Each building component has a different predicted life-cycle cost as well as original cost. Differences in costs between components of similar functional characteristics are the foundation of life-cycle cost analysis. The specific life-cycle information for each of the building components identified in Table 4.36, and others, was applied for each building according to the procedures specified in ASTM document E917. Examples of differences in building life cycles taken from ASTM E917 and used in the analysis highlight potential cost savings. This appears as a difference in predicted cost to maintain a building with a specific composition relative to a building with a different composition. In this study, only existing building composition is considered.

The results of the analysis, in funding needs per year, for each building appears in Tables 4.37 - 4.42. An additional summary table, showing the average and median funding need per square foot for all facilities is shown in Table 4.43. The data appearing in each of the six tables were generated using the data from ASTM E917. These fundamental costs were provided in both annual and replacement year amounts and divided between material, labor hour, and equipment hour costs. A complete listing of the annual maintenance and repair plus high cost repair and replacement costs is shown in Appendix A. Per hour costs for both labor and equipment rental were determined as described in Chapter 3. The labor costs were available from internal university records beginning in 1953. Assumptions, based on the experience of the author, were made in assigning maintenance tasks to a particular trade. Material costs shown in Appendix A are based on 1985 dollars in the Washington D.C area. Inflationary and area adjustments are made in accordance with ASTM E917. The Means Historic Construction Cost Index is used to adjust to 1995 dollars. Regional cost differences are adjusted using factors provided in ASTM E917.

TABLE 4.37

FINE ARTS LIFE CYCLE COST ANALYSIS ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$0	$0.00	0.00%
10	$1,000	$0.02	0.01%
15	$66,639	$1.09	0.35%
20	$2,155,559	$20.40	11.28%
25	$1,001,977	$9.58	5.24%
30	$9,460	$0.09	0.05%
35	$539,542	$5.16	2.82%
40	$200,458	$1.92	1.05%

Table 4.37 identifies the recommended annual expenditures for the Fine Arts Center in five-year increments. There is drop in recommended expenditures per gsf when the building is over 20-years old resulting from the addition of new space to the building that did not require major maintenance expenditures. Another large change in recommended expenditures occurs when the building is 15-years old due to a recommended expenditure of $2,146,128 to replace door hardware, hot water piping insulation, cooling towers, and terminal reheat units in the same year. Other minor expenditures for equipment replacement or material restoration are done at age 15 but not to a significant amount. The next large expenditure for replacement or restoration is at age 20. An expenditure of $870,737 is recommended to replace several components in the air-conditioning system. Major expenditures are

recommended in the 1972 addition when it is 15-years old. These are similar to earlier expenditures recommended in the original building and include cooling towers and terminal reheat units. Future major expenditures, not shown in Table 4.37, will be required when the original building is 40-years old and 75-years old when plumbing systems require replacement.

TABLE 4.38

LIFE SCIENCE COMPLEX LIFE CYCLE COST ANALYSIS
ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$0	$0.00	0.00%
10	$4,103	$0.07	0.04%
15	$17,292	$0.29	0.15%
20	$869,496	$14.41	7.62%
25	$543,901	$9.01	4.77%
30	$31,713	$0.53	0.28%
35	$541,283	$8.97	4.74%

Table 4.38 identifies the recommended expenditures for the Life Science building and Annex in five-year increments. Sixteen years after occupancy of the building, the component method predicts a need for $481,685 for major maintenance. The high expenditure need is to replace terminal reheat units, door hardware, and electrical devices. These expenditures are similar to those identified for the Fine Arts building in Table 4.37 because the buildings have similar components. Other large expenditure needs are when the building is 20 and 30 years old.

TABLE 4.39

COLEMAN HALL LIFE CYCLE COST ANALYSIS ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$0	$0.00	0.00%
10	$17,824	$0.16	0.09%
15	$209,828	$1.86	1.11%
20	$459,658	$4.07	2.42%
25	$195,920	$1.73	1.03%
30	$238,103	$2.11	1.25%

Recommended expenditures for Coleman Hall and its addition are shown in Table 4.39 in five-year increments. The first fourteen years of building occupancy show recommended expenditures for minor maintenance only. In 1980, when the original building is 15 years-old, recommendations to replace door hardware, terminal reheat units, and the cooling towers result in a large increase in maintenance expenditures. These items require approximately $210,000 more than would otherwise be anticipated from annual maintenance expenditures. Recommendations for large expenditures also occur when the building is 17-years old, $178,000; 20-years old, $192,000; 22-years old, $185,000; and 30-years old, $190,000.

The peak year shown in Table 4.39 is 1995. The original portion of the building is 30 years old and the addition is 28 years old. These high costs are required for cooling tower replacement and terminal reheat units among others. Future years requiring high expenditures are when the building is 40 and 75 years old.

TABLE 4.40

KLEHM HALL LIFE CYCLE COST ANALYSIS ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$0	$0.00	0.00%
10	$5,127	$0.06	0.03%
15	$11,552	$0.14	0.08%
20	$383,221	$4.64	2.61%
25	$380,483	$4.61	2.59%
30	$40,694	$0.49	0.28%

Klehm Hall recommended expenditures in five-year intervals are shown in Table 4.40. High expenditure years age 15 and 20 when $325,000 and $380,000 respectively are required. Expenditures at age 15 are for door hardware and terminal reheat units and replacing the cooling tower. Expenditures at age 20 are largely for replacing central steam radiation units that make up this laboratory building. Other large expenditures are anticipated for ages 30 and 50 to replace the fire alarm system and electric distribution equipment respectively.

TABLE 4.41

LANTZ GYMNASIUM/FIELDHOUSE LIFE CYCLE COST ANALYSIS ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$0	$0.00	0.00%
10	$5,334	$0.03	0.02%
15	$16,766	$0.08	0.05%
20	$591,805	$2.81	1.70%
25	$472,594	$2.24	1.36%
30	$173,112	$0.82	0.50%

Lantz Gymnasium and Fieldhouse have several large, open areas that meet the functional requirements of the building. The building does not require significant expenditures until it is 15 years old, 1981, when $434,000 is required to replace door hardware, fire alarm equipment, and terminal reheat units. Major expenditures of $469,000 in 1986 are to replace distribution piping for heating and cooling systems as well as domestic water systems. The only other noticeable peak in recommended expenditures during the study period occurs in 1994, which is $162,000 above the previous year. Future large expenditures are recommended at ages 30, 40 and 75.

TABLE 4.42

PHYSICAL PLANT LIFE CYCLE COST ANALYSIS ANNUAL FUNDING RECOMMENDATIONS IN 1995 DOLLARS

Age	Total Recommendation	Expenditure per GSF	Percent of CRV
5	$452	$0.01	0.01%
10	$4,860	$0.14	0.09%
15	$20,213	$0.60	0.38%
20	$21,322	$0.63	0.40%
25	$17,794	$0.53	0.33%
30	$57,724	$1.72	1.08%

The Physical Plant building, while experiencing peak maintenance recommendations at ages 14, 19, 27, and 29 has annual funding recommendations less than those of other buildings. This is due to fewer components present in the building for occupant comfort. The Physical Plant has a high proportion of unfinished surfaces and large open work areas. Specialized equipment for maintenance operations is not included in the cost to maintain the building because no comparable components were found in the ASTM database.

TABLE 4.43

SUMMARY OF BUILDING COMPONENT LIFE CYCLE COST ANALYSIS OF SIX BUILDINGS DOLLARS PER SQUARE FOOT (1995$)

Year	FA	LS	CH	KH	LG	PP	Avg.	Mean
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.64	0.07	0.00	0.00	0.00	0.01	0.12	0.01
1975	20.60	0.29	0.16	0.06	0.03	0.14	3.55	0.15
1980	9.58	14.41	1.86	0.14	0.08	0.60	4.44	1.23
1985	0.09	9.01	4.07	4.64	2.81	0.63	3.54	3.44
1990	5.16	0.53	1.73	4.61	2.24	0.53	2.47	1.99
1995	1.92	8.97	2.11	0.49	0.82	1.72	2.67	1.82

Average costs for maintenance of these six buildings range from a low of $0.00 to a high of $20.60 per gross square foot. Similarly, Table 4.44 shows the percent of CRV predicted for major maintenance.

TABLE 4.44

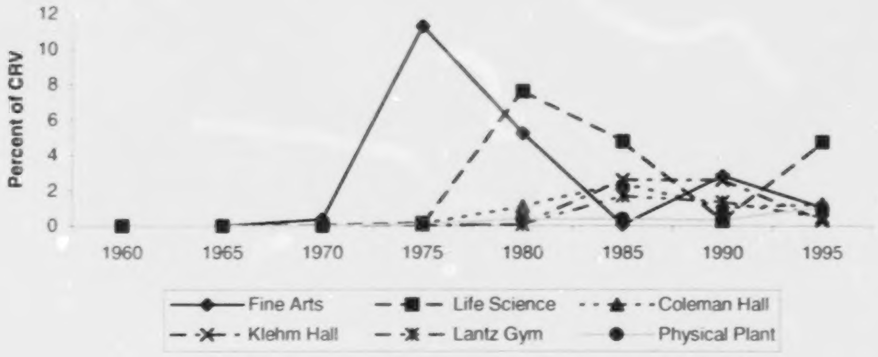
SUMMARY OF BUILDING COMPONENT LIFE CYCLE COST ANALYSIS OF SIX BUILDINGS PERCENT OF CRV

Year	FA	LS	CH	KH	LG	PP	Avg.	Mean
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.35	0.04	0.00	0.00	0.00	0.01	0.07	0.00
1975	11.28	0.15	0.09	0.03	0.02	0.09	1.94	0.09
1980	5.24	7.62	1.11	0.08	0.05	0.38	2.41	0.74
1985	0.05	4.77	2.42	2.61	1.70	0.40	1.99	2.06
1990	2.82	0.28	1.03	2.59	1.36	0.33	1.40	1.20
1995	1.05	4.74	1.25	0.28	0.50	1.08	1.48	1.06

The high and low differences for a single building can be found by examining the differences between Fine Arts (FA) expenditures in 1958, the first year of occupancy, and 1973, the fifteenth year of occupancy. A low of $0.00 to a high of $20.51 per gross square foot is shown. So the organization maintaining a facility of this type must allocate over eleven percent of current replacement value for the twentieth through twenty-fifth years of operating this facility in order to maintain the building in "like-new" condition. A graph of these results appears in Figure 4.14 and is comparable to Figure 4.13

FIGURE 4.14

BUILDING COMPONENT LIFE CYCLE COST ANALYSIS
IN 5-YEAR INTERVALS COST PERCENT OF CRV



The equipment life-cycles which result in this large expenditure differential over previous annual expenditures are several. Equipment listed with a twenty-year life include architectural items: weather stripping and windows; plumbing items: hose bibs and fire sprinkler heads; HVAC items: steam radiation controls and exhaust fans; and electrical items: power receptacles and fluorescent lights. The expenditure recommendations would replace all these items throughout the building.

Similarly, large differences between consecutive years are important to investigate. Large differences occur again with Klehm Hall between 1985 and 1987 (the 19th and 21st years). In 1985 the annual recommended expenditure is $0.67 per gross square foot. In 1987 the recommendation is $4.61 per gross square foot. The repairs that consumed these expenditures are described above.

Differences in annual maintenance cost predictions are observed when charted against age. Table 4.45 shows the annual expenditure predictions for each of the six buildings over a 30-year span. All costs are in 1995 terms.

TABLE 4.45

FIVE YEAR EXPENDITURE RECOMMENDTIONS
FOR SIX SAMPLE BUILDINGS IN 1995 DOLLARS

Age	FA	LS	CH	KH	LG	PP	Avg.	Mean
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.14	0.07	0.05	0.06	0.03	0.12	0.08	0.06
15	0.51	0.29	0.11	0.14	0.08	0.04	0.20	0.13
20	21.58	14.41	4.22	4.64	2.81	0.65	8.05	3.60
25	8.63	9.01	3.38	4.65	2.24	1.00	4.82	3.45
30	3.71	0.53	0.48	3.34	0.82	1.12	1.66	0.50

The maintenance costs for each building are the same across the 30-year time period examined in Table 4.45 when investigating one building at a time. Maintenance costs are not the same for buildings of the same age. Average maintenance costs over the 30-year period for each building are: 0.71% for Fine Arts, 0.50% for Life Science, 0.17% for Coleman Hall, 0.26% for Klehm Hall, 0.12% for Lantz Gymnasium, and 0.06% for the Physical Plant. The Fine Arts building has recommended major maintenance expenditures 1.4 times greater than Life Science, four times greater than Coleman Hall, three times greater than Klehm Hall, six times greater than Lantz Gymnasium, and twelve times greater than the Physical Plant. Reasons for these differences are described below.

The total costs for each of these buildings can be compared to the building condition index (BCI) method for assessing facilities as described above. Comparison of total recommended annual expenditures by the life cycle cost component method to the BCI provides a means to compare the component method against the other models that have been measured against the BCI.

Recommended major maintenance expenditures for the Fine Arts building following the life-cycle cost building component method were $3,974,636. This results in a predicted building condition index of 22.3 when actual expenditures for major repairs and replacements are removed. Comparing this against the field measured building condition index of 49.0 shows that the building component method under-predicts the major repair and replacement expenses necessary to maintain the building. Similar results for the other five buildings are shown in Table 4.46 with the Fine Arts results.

TABLE 4.46

PREDICTED BUILDING CONDITION INDEX USING LIFE-CYCLE COST BUILDING COMPONENT MAINTENANCE EXPENDITURE RECOMMENDATIONS THROUGH THE YEAR 1995

Building	LCC Component Expenditure Recommendation	Predicted Building Condition Index	Actual Building Condition Index
Fine Arts	$3,974,636	22.3	49.0
Life Science	$2,007,788	18.6	42.8
Coleman Hall	$1,121,332	2.5	39.6
Klehm Hall	$821,078	6.4	43.0
Lantz Gym	$1,259,612	3.6	48.0
Physical Plant	$122,366	2.5	34.2

The predicted building condition index resulting from the building component life cycle cost analysis is higher for the Fine Arts and Life Science buildings than the other four buildings. This is an expected result due to the higher proportion of mechanical and electrical systems to support activities in these two buildings. Coleman Hall is primarily a classroom and office building and has no special equipment for laboratory or research activities which would result in larger equipment replacement expenditures over its life. Klehm Hall, while having several laboratory and special use facilities, has fewer amenities requiring maintenance. Laboratories have plain concrete floors, painted block walls and exposed ceilings and mechanical systems. Many of the corridors in Klehm Hall are brick and have a much longer life cycle than plaster/sheetrock walls which are more prevalent in the Life Science complex, Coleman Hall and Fine Arts Center.

Lantz Gymnasium has a small number of air-conditioned areas and has many large open areas that reduce the amount of different surfaces, pieces of equipment, and materials that must be maintained. An investigation of the material maintenance costs in Appendix A show considerably higher maintenance costs for carpet and vinyl tile over ceramic tile floors, the common flooring in the locker room areas in Lantz Gym. Annual maintenance costs of 0.00001 hours of labor per square foot for ceramic tile floors versus 0.00002 for vinyl tile and 0.00003 for carpet result in significant annual cost differences. These cost differences are further magnified by annual material costs of 0.00002, 0.00296, and 0.00081 per square foot for ceramic tile, carpet, and vinyl tile respectively. Life cycles of 50, 8, and 18 years for ceramic tile, carpet, and vinyl tile respectively increase the cost differences again. These and other factors combine to make the maintenance costs for Lantz Gym, a 210,919 square foot facility less expensive to maintain than the other classroom, office, or laboratory facilities examined as is shown in Table 4.41.

The Physical Plant is the least expensive to maintain because it has fewer amenities than Lantz Gym. Tables 4.41 and 4.42 demonstrate the lower maintenance costs in annual terms with the major maintenance costs included. In 1972, when the Physical Plant is eight years old, major maintenance expenditures are recommended on carpet in the office areas. The maintenance costs per gross square foot do not exceed any of the other facilities' costs per gross square foot without major maintenance expenditures.

4.5.4 Summary of LCC Methods

The building component life cycle cost method does not accurately predict the building condition index for any of the buildings in the sub-sample. The closest buildings are the Fine Arts center and Life Science complex. These are high use, expensive component buildings. The building condition index, predicted by the component life cycle cost method, differs from the measured building condition index by a factor of more than two. Differences in predicted building condition index for the other four buildings, Coleman Hall, Klehm Hall, Lantz Gym, and Physical Plant exceed a factor of eight, and in some cases, ten. This means the life cycle component method greatly under-predicts the wear to the building as evaluated.

When comparing the component life cycle cost method's major expenditure recommendations against the rule of thumb of 1.5% to 3.0% of building replacement value annually, the recommendations fall far short. In 1995, the estimated per square foot replacement value of the six buildings was $184.69 for Fine Arts, $200.29 for Life Science, $139.30 for Coleman Hall, $171.78 for Klehm Hall, $215.38 for Lantz Gym, and $200.88 for the Physical Plant. Following rule of thumb of 2%, an average expenditure for these facilities should be between $2.79 and $4.31 per gross square foot for major repair and replacement tasks only. The average component life cycle cost method predicts between $0.10 and $1.15 per gross square foot, including annual maintenance expenditures. This is less than one half of the rule of thumb expenditure.

The recommended expenditures for major maintenance and rehabilitation of buildings following the Component Life-Cycle Cost methods are consistently lower than the three simpler college and university facility funding models, depreciation, formula funding, and facility formula funding. When annual costs are included in the life-cycle cost method, the recommendation is closer to the other models.

Differences in annual and major maintenance costs are most prominent between buildings which house technical/scientific programs and those that house non-technical or administrative programs. The Fine Arts building is identified as technical/scientific because of the general nature of the building rather than the program it contains. Although art, music, and theater activities which are "soft" in curriculum, their programs require technical facilities similar to the facilities of the Life Science Complex. Technical facilities have more plumbing, ventilation, electrical service, and controls equipment. Therefore, these technical facilities require more annual maintenance expenditures per gross square foot than non-technical facilities that do not have the extensive support equipment.

Likewise, the Fine Arts Center contains rooms and finishes which are more expensive to maintain. Expensive finishes include wood paneling, special wood trim ceilings, carpet, and acoustic panels. The large number of small rooms, practice rooms for music students in particular, contribute to higher maintenance costs due to the large number of doors and higher area of walls relative to buildings which contain fewer rooms. When major maintenance costs are studied, the differences between the individual facility operational costs becomes more pronounced. Costs to repair or replace major equipment of building components are pronounced when they occur in congruent years. In the sub-sample, this occurs in 1987 when there are peaks in recommended expenditures for Fine Arts, Coleman Hall, Klehm Hall, and the Physical Plant. The maintenance demands of the buildings are generally well distributed so that these peaks do not occur in a single year but appear gradually in a steadily increasing trend.

4.6 Curve Fitting of Models

As described in Chapter 3, a variety of models have been collapsed into a general rule of thumb which indicates that annual renovation and renewal funding should fall between 1.5% and 3.0% of total building replacement value (Dunn, 1989). This range, because of historic precedence, is considered a region of valid solutions. In this part of the analysis, the outcomes of the various models are studied to determine if they fall within this region through linear regression techniques. Linear regression is used because of its relatively simple formulation and similarity to the rule of thumb that identifies a linear rate of funding. The models are compared to this region. A subsequent comparison will be made between the models and the results of the building condition audits for concurrence. An analysis is conducted on the entire sample and on individual buildings in the sample. Comparisons are made between different space types as well as different building ages. The straight line depreciation method is not examined because it has a constant 2% of CRV funding recommendation.

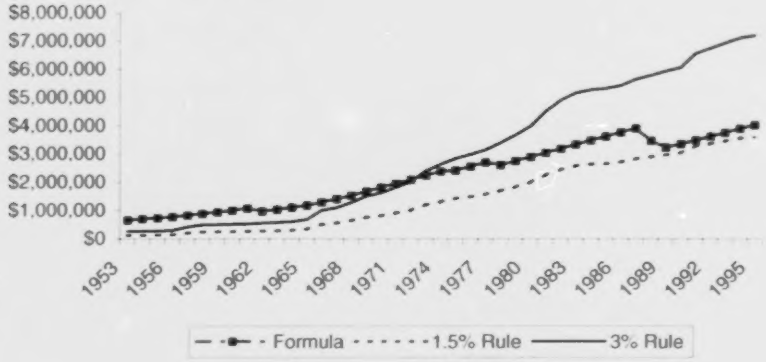
4.6.1 Formula Funding

Figure 4.15 provides a comparison of the age-based formula funding model to the annual funding range of 1.5% to 3.0% of building replacement value between the years 1953 and 1995. This figure demonstrates that the age model falls outside the funding range between 1953 and 1982. At the beginning of that period, one building is over 50 years old. It is not included in the model. If major renovation work had been performed in the initial 50 year period its theoretical age in the formula could have been reduced and would not have fallen out of the formula or funding model.

Between 1953 and 1982, two additional buildings reach their maximum age and contribution to the formula model and drop out of the calculations. Thirty buildings were constructed between 1949 and 1982. The contribution to the formula is smallest for young buildings, as described by Kraal (1992). They do not begin to have a significant effect until they reach an average of at least nineteen years when the result of the formula, 19/1275, is 1.5%. Prior to 1982 all buildings in the sample are depreciable in the method and have an average age of 18.2 years, a mean age of 16 years. After 1982, four facilities fall out of the model calculations from old age. The average age of buildings after 1982 is 19 years. The Formula Funding model reaches 1.5% in 1983 and is close to 1.8% by 1995.

FIGURE 4.15

COMPARISON OF FORMULA FUNDING MODEL
AGAINST THE UPPER AND LOWER
RULE OF THUMB MAINTENANCE
EXPENDITURE RECOMMENDATIONS

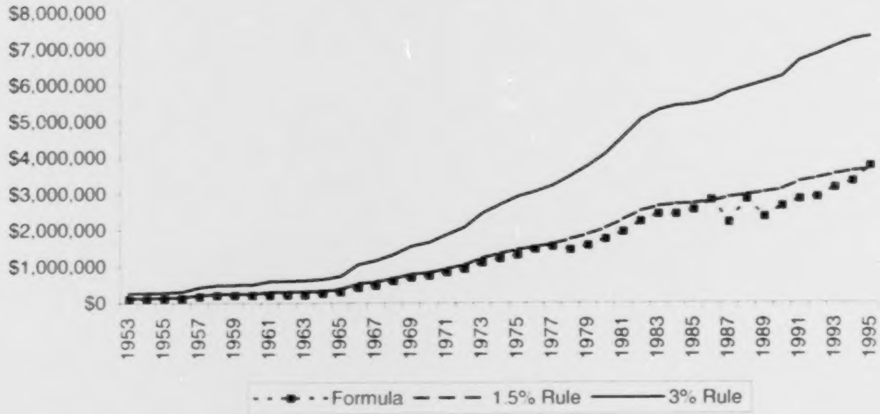


4.6.2 Facility Formula Funding

Figure 4.16 provides a comparison of the results of the Facility Formula Funding model to the 1.5% to 3.0% funding range. The Facility Formula Funding model never approaches the recommended funding region because of the factors contained in the formula assume 1/3 of the building does not wear out "under normal maintenance" (IBHE, 1995) or require inclusion in funding calculations. In addition, an effective funding life of 100-years is recommended. This halves the annual recommended funding level compared to the other models. A change to a 50-year life for buildings results in a funding level of 1.67% and within the 1.5% to 3.0% funding range recommended as a general rule of thumb.

FIGURE 4.16

COMPARISON OF FACILITY FORMULA FUNDING MODEL AGAINST THE UPPER AND LOWER RULE OF THUMB MAINTENANCE EXPENDITURE RECOMMENDATIONS



When one examines the funding rule closely an interpretation of a 50-year life can be accepted and thus the model falls within the range of acceptable values. The model assumes that the university will, at some point within the 100 years identified, obtain funding to totally renovate the facility and return it to "like new" condition. "Like new" means a building condition index of 0, a calculated age of 0 as described by the Sherman & Dergis facility model, and with new equipment and materials, as tracked by the LCC models, for 67% of the building. The 33% remaining is assumed to include foundations, structure, and "permanent" exterior skin which have a theoretical infinite life. Thus this method, when properly applied and understood, can yield acceptable results.

4.6.3 Building Condition Index

This method identifies funds required based on actual observed conditions determined through an audit of the facility. Ideally, there will be data points from the audit at regular intervals and therefore a curve fitting technique will have regular data with which to operate. While regular data is not a necessary condition of a linear regression, it would meet sufficiency requirements of linear regression by providing needed data. This is not the case with the facilities in the sample. The university had no system in place prior to 1987 to periodically assess the condition of buildings. There was no particular concern about investing in the buildings beyond remodeling activities or to managing imminent failures of building components. This administrative decision has provided some useful and easily interpretable data with which to draw some reasonable assumptions for this analysis.

The primary concern with a curve fitting analysis of the buildings is to determine the validity of the existing data. This was the first step prior to performing the analysis. Each building was assumed to have no deferred maintenance at the time it was constructed and occupied. This assumption is consistent with the other funding models that either recommend little or no funding for major maintenance projects in the first five years of building life. When the building is new all components, have very little wear, and meet the building codes and standards of the time. Building codes typically have a three-year cycle before a new code is developed and published. The opportunity for a building to become immediately non-compliant with current building codes is limited. Likewise, building codes typically reflect the minimum acceptable standard of good design practices and change slowly over time. Thus, a well-designed facility can survive more than one code revision cycle remaining compliant with current building codes. This last element has been confirmed by reviewing the available plans and specifications with respect to historical information about building codes and standards.

The second set of data points was determined in 1987, during a mandated audit of all facilities on campus. The audit was conducted by on-campus personnel familiar with the buildings and knowledgeable of the working condition of the various building components. A systematized assessment instrument was then used to combine information from the different people involved in the audit. The assessment instrument developed by Bareither (1984) provided for a numeric means to rate each facility. A validation audit was then performed on a subset of the facilities by outside architectural and engineering experts. The overall audit was then compared with the validation audit in order to determine the accuracy of the larger dataset. The results of the validation audit indicated the building condition indices arrived at by the on-campus staff were accurate within approximately 10%. This level of accuracy has been shown to exist through historic application of the audit according to its creator, Bareither (1995). The on-campus assessment generally provided a more conservative building condition index (higher) than the off-campus consultants. This over-assessment was typical across the other four campuses evaluated in the study. A subsequent audit, inspired by this research effort, was conducted in 1995 on the same sample. The same people who performed the 1987 audit were enlisted to repeat the audit in 1995. Their knowledge of the sample and how it had changed during the intervening eight years, was utilized to develop the new audit.

The curve fitting of the results of the initial conditions and two audits is done using standard mathematical techniques. A limited number of data points were available, an initial point assumed to be zero when the building was new, a second point resulting from the 1987 survey, and a third point being the 1995 survey. The BCI survey results were modified to eliminate the effects of renovation and repair work performed over the building life. This step makes it possible to create a measure of rate-of-decay for the buildings in the study. A linear regression method was used to perform the analysis on an aggregate of buildings, all buildings in the sample and only those buildings constructed between 1957 and 1973 that exhibit similar construction characteristics. The method is recognized as being accurate only within the range of the existing data. It cannot be used to extrapolate future data. It is not anticipated to provide sufficient accuracy to make predictions for future funding needs. It was selected to see if a consistent trend in the use of building audits could be developed which would verify other funding prediction methods.

Figure 4.17 shows the regression curve fitted through the entire data set. Building age was used as the independent variable and building condition index was the dependent variable. Every building has a datapoint at the origin due to the assumption that there is no deferred maintenance in a building when it is new. All other datapoints shown in the graph are from the two surveys of building condition by building age and adjusted as described.

The older buildings in the sample make up the outlying data points beyond forty years. The newer buildings make up the data points less than 10 years old. These datapoints are widely scattered compared to the data available from the buildings constructed in a more limited span of time, between 1957 and 1973. While the youngest buildings in the sample are of similar construction to the majority of buildings, they are outside the bulk of data in the sample.

The resultant regression curve shown in Figure 4.17 passes the ordinate well away from the origin. This does not agree with the assumption that there is no deferred maintenance when a building is new. The slope of the curve is equal to a recommended funding level of 0.80% of current replacement value. This is below the level of 1.5% from the rule of thumb and close to the facility formula funding recommendation of 0.67%.

FIGURE 4.17

BUILDING CONDITION INDEX VS. AGE, ALL BUILDINGS, ASSUMED INDEX OF ZERO WHEN NEW

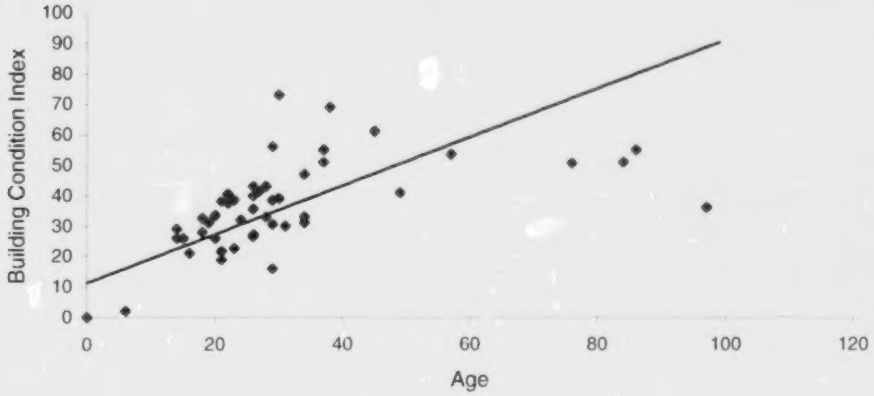


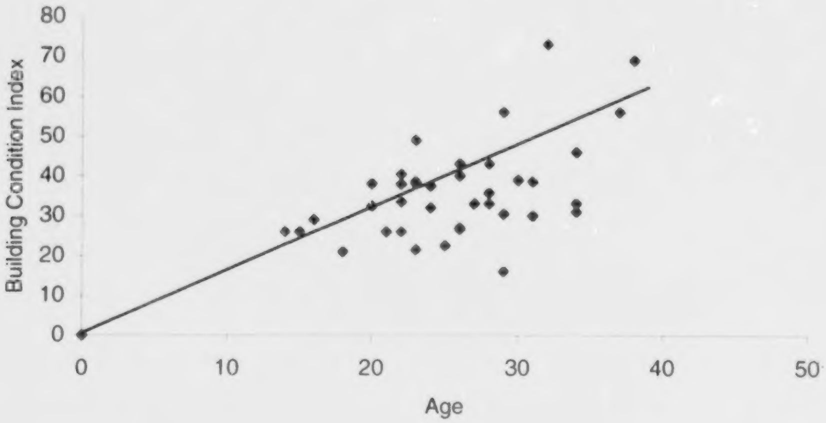
Figure 4.18 shows the regression curve fitted through a subset of data consisting of only the buildings constructed between 1957 and 1973. Every building has a data element at the origin. The youngest building is 14 years old at the time of the first building condition audit. The oldest building is 38 years old at the time of the second building audit.

Building conditions are mostly reported between 20 and 50 with some outlying buildings that are assessed to be considerably worse, 60 or more. The buildings that have the higher building condition index are the older buildings. This is consistent with the assumption that buildings gradually get in worse condition over time.

The regression analysis results in a line that passes close to the origin, similar to the data shown in Figure 4.18. The slope of the regression curve is equal to a building reinvestment rate of 1.58% of building replacement value. This is within the rule of thumb range for major maintenance funding. The regression curve predicts a building condition index of slightly over 69 at a building age of 50, the end of the building's depreciable life. This is consistent with the assumption of some researchers that approximately two-thirds of a building does not wear out.

FIGURE 4.18

BUILDING CONDITION INDEX FROM ZERO WHEN NEW AND 1987 AND 1995 SURVEYS FOR BUILDINGS CONSTRUCTED BETWEEN 1957 AND 1973



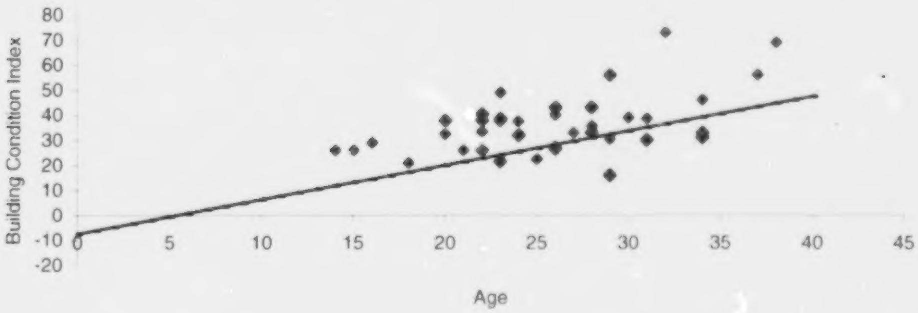
A third linear regression analysis was done on the buildings constructed between 1957 and 1973 with the zero age data points removed. This data is based solely on the survey results of the two building audits conducted in 1987 and 1995. The data and resulting regression curve are shown in Figure 4.19. The slope of the regression curve changes to more shallow and moves below the origin. The ordinate intercept becomes negative and the slope of the regression curve becomes more shallow and equal to a recommended funding level of 1.37% of current replacement value. This is less than the rule of thumb funding level and about twice the rate used by the formula funding method.

There are outlying datapoints shown in Figure 4.19. The data points with the higher values are generally the older buildings. Ignoring the initial condition of a zero BCI when the building is age zero shifted the regression curve down. It appears that is an overly generous assumption for the group of similarly constructed buildings. There were no buildings of radically different construction to compare with this group without including other factors such as age. The exclusion of the older buildings, greater than 50-years old, from the regression analysis has a significant effect on improving the accuracy of the resultant function.

However, in no case is the regression curve significantly accurate. The curve in Figure 4.17 has a standard deviation of 23. The curve in Figure 4.18 has a standard deviation of 13. The lowest standard deviation existed with the data as shown in Figure 4.19 is 6. This level of accuracy can result in an error greater than $0.6 million when making predictions for the repair of a $10 million building. This error is large in absolute terms and large enough to be considered significant in relative terms. It is within the predicted level of accuracy of the BCI survey method and is considered a good result.

FIGURE 4.19

BUILDING CONDITION INDEX FROM 1987 AND 1995 SURVEYS FOR BUILDINGS CONSTRUCTED BETWEEN 1957 AND 1973



4.6.4 CERL Model, Constant Costs

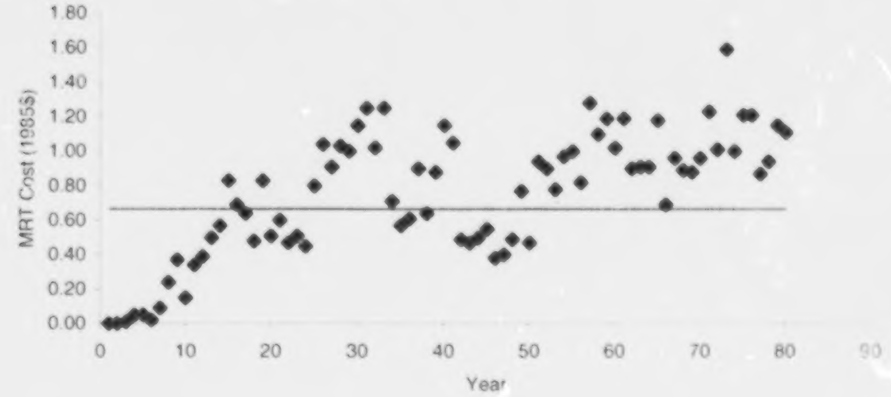
The first of the USA-CERL models, that of constant annual expenditures for major maintenance projects, results in a constant rate of funding needs. Actual determination of this rate, for comparison with the range of acceptable solutions, requires comparison against construction costs of the same period, the model is based on 1985 data. The current replacement values (CRVs) for these spaces was determined from 1985 IBHE CRV information by using comparable facilities. The average cost of university facilities in Illinois in 1985, adjusted by the geographic Area Cost Factors (ACF) result in a recommended expenditure rates between .77 and 1.73% of building current replacement value. Since the expenditures do not change with building age or time other than inflationary adjustments, there is no need to develop the analysis further. These rates fall generally below the rule of thumb range of 1.5% to 3.0% for annual expenditures.

4.6.5 CERL Model, Age Varying Costs

The second of the USA-CERL models, that of the annual expenditures varying with facility age for major maintenance projects, results in a wide range of annual funding needs. Figure 4.20 is a graph of the data provided in Table 4.16, recommended expenditures for general purpose administration buildings which are similar to the university office space type. There are three peaks in the funding recommendations. These peaks occur in the 31st, 57th, and 73rd years of the building's life. These peaks are not anomalous data points because of several other high expenditure recommendations on either side of the peak years, they are a reflection of life-cycle cost requirements. The average recommended expenditure, identified in Table 4.16, over a 50-year period is $0.75 per square foot. When this is compared against an estimated current replacement value of a similar university space type in 1985 of $94.18 per square foot or 0.80% of current replacement value. This is less than the minimum recommended range of 1.5% and similar to the facility formula funding rate of 0.67%. The mean of recommended expenditures is $0.83 per square foot. Most of the funding recommendations shown in Table 4.16 identify an expenditure of less than $1.00 per square foot per year (1.1%), in constant 1985 dollars. There are twenty-one years where the recommendation exceeds $1.00 per square foot per year and of these none exceed a recommendation of $2.00 per square foot per year, 2.2% of the estimated current replacement value.

FIGURE 4.20

USA-CERL DATA FOR GENERAL PURPOSE ADMINISTRATION MAJOR REPAIR AND REPLACEMENT TASKS



This is different from the recommendations for an instructional building, shown in Table 4.48 and Figure 4.21. In this case, there are two distinct peaks in funding recommendations, in the 31st and 61st years.

TABLE 4.47

ANNUAL COSTS (1985$) FOR MAJOR REPAIR AND REPLACEMENT TASKS (MRT) FOR US ARMY INSTRUCTIONAL BUILDINGS

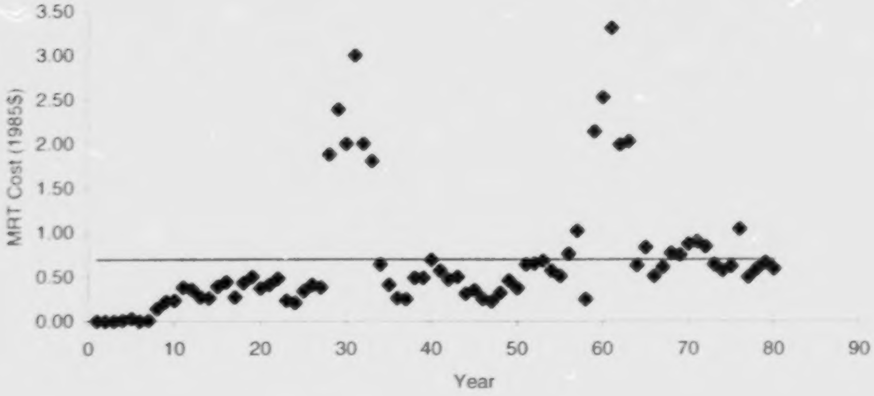
Year\ Decade	1	2	3	4	5	6	7	8	9	10
0	0.000	0.000	0.000	0.010	0.030	0.000	0.010	0.140	0.220	0.230
1	0.380	0.360	0.270	0.260	0.390	0.440	0.270	0.430	0.500	0.370
2	0.410	0.480	0.230	0.210	0.340	0.410	0.380	1.880	2.390	2.000
3	3.000	2.000	1.810	0.640	0.410	0.260	0.250	0.490	0.490	0.690
4	0.570	0.470	0.500	0.310	0.350	0.250	0.220	0.320	0.460	0.370
5	0.640	0.650	0.580	0.570	0.510	0.760	1.020	2.480	2.140	2.530
6	3.310	1.990	2.030	0.630	0.830	0.510	0.610	0.770	0.750	0.870
7	0.900	0.840	0.640	0.570	0.620	1.040	0.500	0.590	0.660	0.590

Figure 4.21 is a graph of the same data as in Table 4.47, with a least squares fit curve for the data shown. This data produces an average annual recommended expenditure

of $0.70 per gross square foot against estimated current replacement value of $94.18 or 0.74%. The rate of increase in the annual expenditure by the least squares fit method is 0.01 per year resulting in a final regression-based recommendation of $1.19 per square foot or 1.3% of current replacement value. This is also below the recommended range of 1.5% to 3%. There is only one year in which the recommended expenditure for general purpose administration, offices, falls within the recommended range of expenditures, and that is year 73, with $1.59.

FIGURE 4.21

USA-CERL DATA FOR US ARMY INSTRUCTIONAL BUILDINGS MAJOR REPAIR AND REPLACEMENT TASKS



4.6.6 CERL Model, ARM and MRT Costs

A second iteration of this model was performed using these same annual square foot costs recommendations by space type. This was done using four different combinations of spaces. The army space types were selected based on descriptive similarity to the university space types. The analysis results appear in Table 4.48. The table includes analysis results from all buildings in the sample between the years 1945 and 1995. Adjustments for historic costs utilize the Means Cost Index. Buildings with ages less than 80 years are included in the analysis because the USA-CERL data allows buildings of that age. Once a building reaches 81 years of age it is dropped from the analysis. Four different combinations of space comparisons were used. The comparative space types are listed in Table 4.50. Because no residential spaces were analyzed there are no comparative spaces of that type used.

TABLE 4.48

USA-CERL ARM and MRT EXPENDITURES, 1995$

Year	Trial #1	Trial #2	Trial #3	Trial #4
1945	$537,771	$375,079	$369,579	$419,623
1946	$546,165	$405,326	$400,025	$438,940
1947	$525,102	$422,274	$415,349	$463,413
1948	$528,228	$402,006	$394,967	$428,105
1949	$553,479	$445,982	$437,776	$491,603
1950	$630,889	$455,941	$445,461	$486,070
1951	$639,885	$516,985	$511,447	$583,037
1952	$693,040	$580,851	$578,787	$598,721
1953	$699,148	$578,145	$568,267	$607,124
1954	$705,198	$548,284	$540,647	$567,210
1955	$711,994	$590,889	$585,491	$620,652
1956	$782,309	$618,012	$608,465	$661,889
1957	$737,150	$632,966	$626,913	$669,480
1958	$897,534	$716,324	$708,625	$809,853
1959	$971,131	$782,744	$764,015	$868,925
1960	$941,540	$742,361	$728,002	$790,346
1961	$959,879	$734,567	$712,034	$777,138
1962	$1,048,499	$760,823	$739,808	$702,101
1963	$973,749	$810,665	$788,048	$846,887
1964	$1,142,822	$867,254	$837,086	$962,577
1965	$1,139,622	$939,710	$917,701	$1,005,012
1966	$1,283,184	$1,089,213	$1,060,648	$1,095,961
1967	$1,695,971	$1,291,630	$1,261,911	$1,532,503
1968	$1,782,033	$1,409,904	$1,394,064	$1,530,743
1969	$2,036,490	$1,599,032	$1,568,060	$1,802,126
1970	$2,118,521	$1,573,600	$1,539,962	$1,720,849
1971	$2,019,708	$1,648,615	$1,604,233	$1,796,361
1972	$2,165,193	$1,675,335	$1,633,831	$1,813,296
1973	$2,065,750	$1,700,563	$1,656,787	$1,822,605
1974	$2,282,694	$1,761,013	$1,712,939	$1,960,405
1975	$2,289,974	$1,710,609	$1,656,620	$1,929,591
1976	$2,238,103	$1,851,789	$1,799,034	$2,054,045
1977	$2,384,934	$1,919,034	$1,857,647	$2,127,435
1978	$2,420,976	$1,940,896	$1,906,728	$2,322,818
1979	$2,330,516	$1,671,538	$1,625,819	$1,949,030
1980	$2,303,892	$1,796,577	$1,738,100	$2,114,594
1981	$2,384,924	$1,861,393	$1,800,876	$2,043,213
1982	$2,483,876	$1,899,984	$1,842,040	$2,096,805
1983	$2,354,788	$1,958,459	$1,878,028	$2,109,932
1984	$2,440,038	$2,031,466	$1,981,045	$2,197,656
1985	$2,549,790	$2,059,237	$1,945,110	$2,186,012
1986	$2,508,939	$2,140,589	$2,078,400	$2,277,587
1987	$2,682,147	$2,279,386	$2,207,754	$2,639,856
1988	$2,658,634	$2,211,294	$2,164,312	$2,492,873
1989	$2,619,955	$2,108,359	$2,066,648	$2,290,314
1990	$2,670,320	$2,079,290	$2,050,467	$2,247,755
1991	$3,188,159	$2,179,273	$2,097,951	$2,376,180
1992	$2,639,578	$2,118,186	$2,088,942	$2,281,432
1993	$3,024,839	$2,185,684	$2,096,195	$2,609,388
1994	$3,225,344	$2,622,119	$2,555,562	$2,845,149
1995	$3,154,224	$2,636,092	$2,555,564	$2,570,181

TABLE 4.49

COMPARATIVE SPACE TYPES ANALYZED
USA-CERL SPACE CODES

Classroom Space Type	Trial #1	Trial #2	Trial #3	Trial #4
Classroom	P4	P2	P2	P4
Dry, Inst. Lab	Q9	Q9	Q9	Q9
Wet, Inst. Lab	P5	P5	P5	P5
Dry, Res. Lab	P7	P7	P7	P7
Wet, Res. Lab	PI	PI	PI	PI
Office	PN	PL	PL	P3
Study, < 1400 sf	QD	QD	QD	QD
Study, > 1400 sf	QB	QA	QD	QD
Special Use	Q5	Q5	QA	QB
General Use	P8	P8	QA	Q5
Support Space	PK	PK	Q5	P9
Medical Care	Q2	Q2	PK	PK

The space codes applied to several different spaces in the US Army building inventory. A listing of the different buildings represented by the codes is listed in Table 4.50 below.

TABLE 4.50

US ARMY BUILDINGS REPRESENTED BY THE USA-CERL SPACE CODES

Code	Buildings Represented
P2	BN Classrooms, BN Administration & Classroom, BN HQ
P3	CO HQ Bldg., Administration & Support
P4	General Instruction, Learning Resource Ctr.
P5	Flight Simulator, Band Training, Applied Instr., Army Res. Ctr.
P7	Maintenance Hanger, Field Maintenance Shop, Paint Shop
P8	Vehicle Maintenance Shop, Electric Maintenance Shop
P9	Vehicle Depot, Quality Assurance Facility
PB	Maintenance Shop, I&R Warehouse
PE	Cargo Building, Storehouse, General Purpose Warehouse
PI	Hospital, Clinic, Laboratory, Morgue
PK	Clinic with or without Beds
PL	General Purpose, Post Headquarters, Division HQ, Engineer
PN	Offices for General, Colonel, LTC, Major, NCO/Enlisted
PU	Enlisted Dining Facility, Officer Dining Facility
Q4	Post Office, Auditorium/Theater
Q5	Entertainment Workshop, Drama Center, Theater w/dressing rms
Q9	Audio/Photo Club, Arts & Crafts Center
QA	Continuing Education Facility
QB	Physical Fitness Center, Gymnasium, Handball Courts
QD	Community Service Center, Library

Comparing the different recommended yearly expenditures for MRT to the CRV over the same period results in the percentages shown in Table 4.51.

TABLE 4.51

USA-CERL ARM and MRT EXPENDITURES, PERCENT OF CRV

Year	Trial #1	Trial #2	Trial #3	Trial #4
1945	1.14%	0.80%	0.78%	0.89%
1946	1.16%	0.86%	0.85%	0.93%
1947	1.12%	0.90%	0.88%	0.98%
1948	1.12%	0.85%	0.84%	0.91%
1949	1.18%	0.95%	0.93%	1.04%
1950	1.34%	0.97%	0.95%	1.03%
1951	1.15%	0.93%	0.92%	1.05%
1952	1.25%	1.05%	1.04%	1.08%
1953	1.26%	1.04%	1.02%	1.09%
1954	1.27%	0.99%	0.97%	1.02%
1955	1.28%	1.07%	1.06%	1.12%
1956	1.41%	1.11%	1.10%	1.19%
1957	1.33%	1.14%	1.13%	1.21%
1958	1.19%	0.95%	0.94%	1.07%
1959	1.11%	0.90%	0.87%	0.99%
1960	1.08%	0.85%	0.83%	0.90%
1961	1.10%	0.84%	0.82%	0.89%
1962	1.20%	0.87%	0.85%	0.80%
1963	1.11%	0.93%	0.90%	0.97%
1964	1.15%	0.87%	0.84%	0.97%
1965	1.12%	0.92%	0.90%	0.99%
1966	1.15%	0.98%	0.95%	0.99%
1967	1.09%	0.83%	0.81%	0.98%
1968	1.07%	0.85%	0.84%	0.92%
1969	1.06%	0.83%	0.82%	0.94%
1970	1.03%	0.76%	0.75%	0.83%
1971	0.98%	0.80%	0.78%	0.87%
1972	1.05%	0.81%	0.79%	0.88%
1973	0.97%	0.80%	0.78%	0.85%
1974	1.05%	0.81%	0.79%	0.90%
1975	1.06%	0.79%	0.76%	0.89%
1976	1.03%	0.85%	0.83%	0.95%
1977	1.10%	0.88%	0.86%	0.98%
1978	1.12%	0.89%	0.88%	1.07%
1979	1.14%	0.81%	0.79%	0.95%
1980	1.10%	0.86%	0.83%	1.01%
1981	1.14%	0.89%	0.86%	0.98%
1982	1.19%	0.91%	0.88%	1.00%
1983	1.12%	0.93%	0.90%	1.01%
1984	1.16%	0.97%	0.95%	1.05%
1985	1.21%	0.98%	0.92%	1.04%
1986	1.19%	1.02%	0.99%	1.08%
1987	1.27%	1.08%	1.05%	1.25%
1988	1.25%	1.04%	1.02%	1.17%
1989	1.23%	0.99%	0.97%	1.07%
1990	1.25%	0.98%	0.96%	1.05%
1991	1.43%	0.98%	0.94%	1.07%
1992	1.21%	0.97%	0.96%	1.04%
1993	1.38%	1.00%	0.96%	1.19%
1994	1.47%	1.19%	1.16%	1.30%
1995	1.44%	1.20%	1.16%	1.17%

As Table 4.51 shows, the USA-CERL based recommended annual expenditures for major repairs and renovations, building renewal, range between 0.75% for a low and

1.47% of current replacement values. This is always less than the lowest part of the generally accepted range of 1.5% of current replacement value and more than 0.75% of current replacement value. Trial #1 has the highest average funding level of 1.18%.

4.6.7 LCC Model, Component Costs

The third life-cycle cost analysis model examines the anticipated maintenance costs for each individual component which make up a given facility. Table 4.52 shows some of the component costs found in Coleman Hall, a typical campus building with a large number of classrooms and offices.

TABLE 4.52

SAMPLE OF COMPONENTS USED TO
ANALYZE LIFE-CYCLE COSTS FOR COLEMAN HALL

Building Component	**Quantity**
Carpet	2,000 SF
Vinyl Tile	71,566 SF
Electrical Switches	660
Fluorescent Light Fixtures	920
Built-up roofing	38,336 SF
Exterior Door Locksets	40
Interior Door Locksets	295
Operable Windows	742
Hot Water piping	4,000 Ft.
Radiation, Distribution Piping	10,000 Ft.
Fans (HVAC equipment)	400

The different building components were counted in order to determine annual expenditures for MRT in each facility. Six facilities were analyzed to this level of detail. They were selected based on the completeness of information available and diversity of space types comprising the buildings.

The analysis results are shown in Table 4.53. The annual recommended expenditures for each building does not form a smooth expenditure rate. Several years have no recommended expenditures. The absence of a recommended expenditure in a given year does not mean that no repairs or expenditures are necessary. In this case, only those repairs that are not considered major repair or replacement tasks (MRT) are identified. Annual recurring maintenance (ARM) is not listed, it continues as valid facility expenses.

TABLE 4.53

MAJOR LIFE CYCLE COST EXPENDITURES BY YEAR PERCENT OF CRV FOR SIX FACILITIES

Age	Coleman Hall	Fine Arts Center	Klehm Hall	Lantz Gymnasium	Life Science Complex	Physical Plant
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7	0.00%	0.01%	0.00%	0.00%	0.01%	0.01%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
9	0.03%	0.20%	0.03%	0.00%	0.02%	0.13%
10	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
11	0.04%	0.11%	0.05%	0.00%	0.06%	0.03%
12	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%
13	0.00%	0.01%	0.00%	0.00%	0.01%	0.01%
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	1.07%	8.75%	2.38%	0.00%	5.02%	0.35%
17	0.03%	0.20%	0.03%	0.98%	0.02%	0.44%
18	1.07%	0.00%	0.00%	0.19%	0.00%	0.00%
19	0.31%	0.54%	0.45%	0.00%	0.46%	0.09%
20	0.31%	0.00%	0.00%	0.23%	0.00%	0.00%
21	1.26%	5.67%	3.09%	0.00%	4.78%	0.85%
22	0.00%	0.00%	0.00%	1.21%	0.00%	0.00%
23	1.26%	0.00%	0.00%	0.00%	0.00%	0.00%
24	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%
25	0.03%	0.22%	0.03%	0.00%	0.02%	0.47%
26	0.04%	0.03%	0.02%	0.01%	0.03%	0.05%
27	0.00%	0.00%	0.00%	0.03%	0.00%	0.10%
28	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
29	0.40%	0.32%	0.32%	0.00%	0.31%	1.65%
30	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%
31	1.42%	9.61%	2.81%	0.00%	5.74%	1.08%
32	0.00%	0.00%	0.00%	0.96%	0.00%	0.00%
33	0.03%	0.20%	0.03%	0.00%	0.02%	0.44%
34	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
36	0.06%	0.06%	0.05%	0.00%	0.03%	0.00%
37	0.42%	0.48%	0.00%	0.03%	0.01%	0.01%
38	0.00%	0.00%	0.00%	0.12%	0.00%	0.00%
39	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
41	1.00%	6.49%	3.51%	0.00%	5.33%	1.00%
42	0.00%	0.00%	0.00%	1.60%	0.00%	0.00%
43	0.00%	0.01%	0.00%	0.00%	0.01%	0.01%
44	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
45	0.00%	0.00%	0.00%	0.00%	0.00%	0.35%
46	0.00%	38.10%	2.44%	0.00%	5.02%	0.00%
47	0.00%	0.00%	0.00%	0.98%	0.00%	0.00%
48	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
49	0.03%	0.20%	0.03%	0.00%	0.02%	0.47%
50	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%

In seventeen cases, out of a possible 300 cases, the recommended expenditure for MRT expenditures meets or exceeds the recommended major maintenance expenditure range of 1.5% to 3.0% of estimated current replacement value of the facility. These cases occur five times for the Fine Arts Center, Klehm Hall, and the Life Sciences Complex and once each for Lantz Gym and Physical Plant. They typically occur in years 16, 21, 31 and 46 when several major replacement tasks occur simultaneously. The components that are typically replaced include water chilling equipment (compressors and absorbers) and terminal reheat units also associated with HVAC. There are several other components, carpet, electrical switch gear, and plumbing fixtures that are recommended for replacement in these years but the costs are not as large as the air-conditioning equipment.

Coleman Hall does not have any year when major building component replacements or upgrades require an expenditure of more than 1.5% CRV. One reason is that it is designed differently from the other four buildings with a lower ratio of individual rooms. This results in a reduced number of components that require scheduled replacement. This building is the largest classroom building on the campus and has more area dedicated to classrooms than offices or other, typically smaller spaces. There are peaks similar to the first four buildings, in years 16, 21, 31, and 41 but are all less than 1.5% CRV.

The Lantz Gym complex has one year when the building component life cycle method identifies expenditures above 1.5% CRV. It has three very large spaces that make up the majority of area and thus reduce the number of components required to operate the building. There are areas with a large concentration of mechanical equipment, such as locker rooms, that have scheduled replacements around year 40 and result in the highest expenditure over a 50-year life. Other peaks occur in years similar to the first four buildings.

The Physical Plant building contains the least number of spaces requiring mechanical equipment to maintain comfort and thus have high maintenance costs. A peak occurs in year 29 when large area space heaters are scheduled for replacement. Smaller peaks occur at times similar to the other buildings to address plumbing and electrical replacements.

The average expenditure for life-cycle major component replacements as a percent of current replacement value over the life of these buildings is 0.46%. This is significantly less than the range minimum of 1.5% normally recommended. Including annual maintenance recommended for the major building components increases the average for the six buildings to 1.53%, at the bottom of the rule of thumb. The range of average 50-year annual maintenance expenditures recommended by the life cycle component model is between 0.48% for Lantz Gym to 3.08% CRV for Life Science.

The Fine Arts Center exhibits the greatest individual expenditures among the buildings studied. The minimum annual expenditure is 1.11% CRV with a maximum of 39.61%. A high level of building finishes, tight temperature and humidity control requirements, and large number of individual rooms contributes to the large recommended annual expenditures. Lantz Gym has the lowest minimum annual expenditure at 0.43% and a peak expenditure of 1.95% CRV. It has a small number or rooms, rough interior finishes, and loose temperature control requirements.

The Life Science complex appears to have the most consistent demand for annual life-cycle maintenance expenditures. The lowest amount recommended is 2.43% and the highest is 8.16% with an average of 3.08% CRV.

Table 4.54 shows the predicted building condition index for each of the six buildings from both the major component replacements and annual life-cycle cost expenditure recommendations.

TABLE 4.54

PREDICTED BCI BASED ON LIFE CYCLE COST FOR MAJOR REPLACEMENTS AND ANNUAL EXPENDITURES OVER FIFTY YEARS

Building	Major Replacements	Predicted BCI	Annual LCC	Predicted BCI	Measured BCI
Coleman Hall	$1,132,601	0*	$5,607,088	12.4	39.6
Fine Arts	$3,838,974	17.0	$10,858,610	52.9	49.0
Klehm Hall	$873,999	5.1	$3,335,145	22.3	43.0
Lantz Gym	$1,440,141	3.2	$6,023,200	13.2	48.0
Life Science	$1,974,371	14.9	$12,528,054	100*	42.8
Physical Plant	$118,589	0*	$565,375	16.5	34.2

- Predicted BCI of "0" is negative, BCI of "100" is greater than 100.

The life-cycle cost methods predict required expenditures well in three of the six cases when both annual and major life cycle costs are included. The major life cycle costs are insufficient to control the accumulation of deferred maintenance. Table 4.54 shows that for Coleman Hall actual expenditures exceeded the major life-cycle recommendations resulting in a negative building condition index. Since the measured BCI is almost 40 this method fails to adequately account for building needs. Similar observations can be made for the other five buildings that have different measured BCI from the predicted BCI.

In two cases, Fine Arts and Life Science, the annual and major life cycle cost recommendations exceed the current replacement value of the buildings and the predicted building condition index that included actual expenditures. The model predicted that expenditures in excess of the CRV must be expended over the fifty-year life. The accumulation of deferred maintenance in these two buildings indicates that they have been neglected. The measured BCI rarely exceeds 67 based on the observation rules. It appears as if other maintenance expenditures may have been made to keep the building operating which were not accounted for in the actual expenditures.

4.7 Summary

This chapter presented several models that were studied and compared against each other and a rule of thumb range of major maintenance expenditures. The simplest models typically fall within the rule of thumb range of 1.5% to 3.0%. The simplest models do not specify in which building major maintenance expenditures should be made nor which component or building subsystem should receive the expenditure.

The more detailed models based on space utilization or on actual components result in lower annual expenditures. The detailed models spell out which building, and in some cases, the subsystem to receive the expenditure. Investigation of the detailed model recommended expenditures by building shows large fluctuations between years. There are occasions when the rule of thumb expenditure is reached or exceeded but only in limited years. The average expenditures by building typically remain well below the rule of thumb recommendation but there are exceptions.

The methods that rely on detailed data have similar errors relative to maintenance expenditure predictions when compared to the models that do not require much data. However, the more detailed models recommend smaller annual expenditures than the less detailed models when specific buildings are investigated.

CHAPTER 5

CONCLUSIONS

5.1 Overview

The purpose of this study is to review several methods that provide information on the forecasting estimates of long range renovation and renewal costs of the higher education facilities and to identify a forecasting method which more accurately predicts funding needs based on non-technical data. This information is intended to provide decision makers at colleges and universities with an appropriate method to determine these costs at their institutions. The study examined two specific questions:

1. Is the USA-CERL data sufficiently similar to colleges and universities to be a predictive maintenance model for college and university facilities?
2. Can a relatively simple model be applied to already existing space data to accurately predict annual expenditures for major maintenance?

These questions are important for several reasons. External sources of maintenance data are beneficial to increase the validity of recommended expenditures. Similarities between model and actual needs are important because the funding levels for renovation and renewal projected by a particular model may provide information regarding the relationship of future requirements to the financial capacity of the institution. A clear understanding of the funding needs in individual buildings both existing and planned will allow for easier justification of expenditures for major maintenance. This information will also assist the users of these models to understand what effect changes in the characteristics of their building inventory will have on model outcome and financial need.

Having high level information which reasonably reflects the major maintenance costs of different types of college and university spaces provides more credible information to university administrators who need quick access to funding needs without requiring them to know the technical and detailed information which make up the facilities capital investment. In addition, this information provides university planners, who are often not involved with maintenance and operations activities, a better sense of the future cost implications of space and programmatic changes.

The study utilized data from buildings comprising the Eastern Illinois University campus. Combinations of buildings by age, function, size, and current replacement value were used to study several different models. The buildings are representative of typical college and university buildings.

A specific time period was examined, 1957 to 1995. This period was selected because of the large percentage in building assets constructed at the beginning of this time and access to the university's spending history on building maintenance. This timeframe includes the period of major construction in United States higher education. This selection also covers up to 78% of the recommended 50-year useful life of buildings in the sample constructed during this timeframe. The study included six buildings constructed before the timeframe representing 22.6% of the total sample in 1987 and 21.6% in 1995. Four of these six buildings reached the age of 50 years during the study period.

The study examined eight models: Depreciation, Age Formula Funding, Facility Formula Funding, Building Component (BRCI), three variations of USA-CERL square foot models, and Life Cycle Costing. Comparisons against observed building condition was used to determine the accuracy of the model to predict funding needs. The final results are presented from the apparent most accurate to the least accurate. A second comparison was made to life cycle cost analysis results in a detailed study of six buildings in the sample.

Inflationary effects are discounted in all comparisons. All models require inflationary adjustments when making future predictions. Construction cost estimating services provide a consistent source of inflation data for this purpose. The complexity of each method varies with the number of data elements and the consistency of the data. In a time when databases of spatial information are required to manage, oversee, and report on a higher education facility are required, the additional complexity of the non-technical models studied here adds little burden.

The deterioration rate of the sample was determined by linear regression of the observed building condition index (BCI) and the building age. The data set which included the assumption that new buildings have a BCI of zero resulted in an average annual expenditure rate equal to 1.49% of CRV. The reinvestment rate of the different models is compared to this observed rate in identifying an appropriate model.

5.2 Results of Models versus Building Condition Analysis

The depreciation and formula models are presented first. The US Army models follow with the BRCI, Life-Cycle Cost analysis, and formula funding between. While the Army has some facilities that are comparable to higher education facilities, it does not track space types in the same manner as higher education facilities and has a wider variety. The application of the USA-CERL models to higher education facilities required the extrapolation of US Army space types to university space types. This was done at three different levels of detail. The first assumed one-to-one mapping of US Army facilities to higher education facilities with the least number of model inputs, i.e., area and space type. The second assumed age-varying data designed to address only major maintenance activities in addition to the other two inputs. The third level included a combination of both constant annual maintenance costs and the age-varying maintenance costs for major maintenance. Testing consisted of several trials of assumed similar facilities against measured building conditions and generally accepted expenditure levels for building maintenance. Each trial used a set of US Army space types mapped to university space types on a one-to-one relationship of gross square feet. The other inputs were mapped directly to determine the fundamental rate of reinvestment in physical plant intended to prevent the accumulation of deferred maintenance. The trials involved the application of a computer program to perform the summation and decisions on which factors to use.

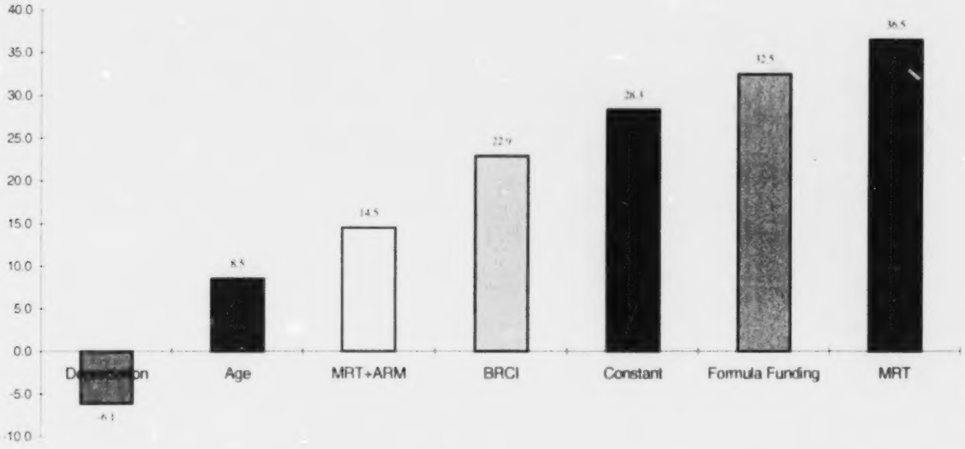
This section compares the predictions of the models against the measured building condition index (BCI). The models are presented in 1995$. The total recommended model expenditure was subtracted from the actual expenditure and divided by the current replacement value to arrive at a predicted building condition index (BCI).

This value was subtracted from the actual building condition index to arrive at a relative measure of model accuracy. The closer the predicted building condition index is to measured index, the more accurate the model. A negative value indicates the model over-recommends expenditures for maintenance to preserve the facility. Over-expenditure is considered a serious error because limited funds are not available for other needs.

The six buildings which were studied in detail using Life Cycle Cost Analysis are used to compare annual and quinquennial spending recommendations. While expenditures over several years in the life of a building, and homogeneous mix of buildings, may be reasonable, limited funds may still be misspent if the model does not accurately reflect varying facility needs. Therefore, close modeling of facility needs for either single or five-year intervals is also important. Five-year results are discussed with the range of difference from the life cycle analysis and the average difference. Close inter-building modeling assists in identification of facility maintenance and allows for better financial planning in support of facility maintenance. A model which can provide a prediction of accurate facility needs is valuable to an administrator who must make decisions about expenditures.

FIGURE 5.1

RELATIVE ERROR OF MODELS, LESS EXPENDITURES AGAINST MEASURED CONDITION
(percent of current replacement value)



5.2.1 Depreciation Model

The depreciation method is the easiest model to implement and operate. The Depreciation (Straight Line) Model most closely predicts the needed expenditures for the long-term maintenance of facilities, although it over-predicts need. Over the study period, 1957 through 1995, the model recommends expenditures of $127,526,300 against actual expendiures of $14,529,501. The predicted BCI by this funding method would result in value of 49.8 versus the actual value of 43.7. Thus the model over-predicts the expenditures by 6.1 percent of current replacement value. This demonstrates agreement with the conclusions of Kraal (1992). Because the depreciation model is based on a 50-year life, it does not include five buildings that are measured in the actual BCI. Those five buildings are dropped from the model, by

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1995, as a result of age exceeding 50 years. When the model is adjusted to incorporate the buildings greater than 50-years old, the model returns a result of -15.2, an over-prediction of $34,615,820 over the study period.

Typical rates of expenditure are between 1.33% and 2% of current replacement value depending on the assumed salvage value of the facility at the end of the 50-year life. The model often falls within the rule-of-thumb range of 1.5% to 3%. However, the model does not recognize the limited needs of young facilities nor the extensive needs of older facilities. This study ignored any salvage value and used a 2% of CRV rate for average annual expenditures.

FIGURE 5.2

PERCENT DIFFERENCE RANGE AND AVERAGE MODEL FUNDING
RECOMMENDATIONS VERSUS LIFE CYCLE COST ANALYSIS
FIVE-YEAR INTERVALS

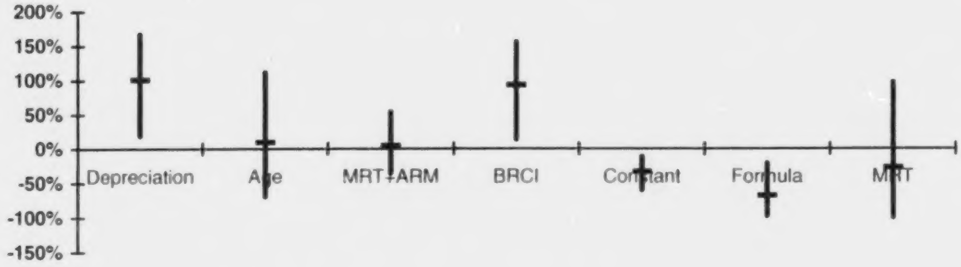

Figure 5.2 shows the difference between quinquennial expenditure recommendations for the various models and life cycle cost predictions for the six buildings studied in detail. The Depreciation model consistently recommends a larger five-year expenditure than the individual building components require based on life cycle

costing. This agrees with the previous figure which indicated that the model over-predicted funding needs. The average error in five-year funding predictions against the LCC model indicates that the Depreciation Model predicts, on the average, 101% more than is required over the life cycle cost needs for the same five year period. The model exhibits the poorest results in buildings with large individual spaces and few amenities. Buildings that have many small spaces with specialized equipment and components are slightly better modeled; but the recommendation is low compared to LCC. The average high recommendation is a result of early year recommendations that recommend expenditures when virtual no expenditure is predicted by the LCC model. In later years, the recommendation for individual buildings, may fall short of the actual need because major systems require replacement.

While the model appears to do a good job predicting funding needs for a large group of buildings of different ages, the model is a poor predictor of funding needs for individual buildings.

5.2.2 Age Formula Model

The Age Formula Funding Method is the next most accurate model when using the building condition criterion. It predicts a building condition index of 35.2 resulting from expenditures made during the study period. This is 8.5 percent below the measured value. However, similar to the depreciation method, five buildings are not included in the calculation in the final years because they have reached an age of 50-years. If the final contribution for a 50-year old building is maintained for the balance of the model, an expenditure of $139,082,356 is recommended resulting in an over-prediction of $26,103,735 or 11.5 percent more than the measured index. This is due to the last model year recommended expenditure for each 50-year old building at nearly 4% of the current replacement value. This means a campus with a large number of older buildings, that have not been sufficiently refurbished so as to reset the age of the building in the model, will demand more for building maintenance than is likely to be required.

When comparing the model to the life cycle cost information for the six buildings studied, the model is less accurate. The model exhibits a wide range of recommended expenditures versus the life cycle cost analysis, from a low of -69% to a high of 112% with the average difference at 10% above LCC. The model over-predicts need in buildings that have large spaces without many amenities. Buildings that have many small spaces with a large quantity of specialized equipment have a under-prediction of funding need with this model.

The model performs almost as well as the depreciation model in general, and is superior at managing funding differences between individual buildings, but it still has significant error when predicting individual building need compared to life cycle cost analysis.

5.3.3 USA-CERL MRT + ARM Model

The MRT+ARM model reflects the continuing costs for maintaining a building and the age varying costs for major component replacements within 14.5 of the measured conditions. Like the MRT model, below, the MRT+ARM model has an 80-year age limitation. This is not considered a limitation because the model, as studied, is adjusted to reflect resetting of the age of a specific space (room) when any significant remodeling is performed. Experience of the author indicates that no individual room will remain unchanged for over 80 years, some renovation will occur and allow the effective age to be reset. The average annual expenditure recommendation using Trial #1 for this model was 1.18% of CRV over the study period. This is 2.75 times the rate of expenditure compared to the MRT-only model. It is also greater than the Constant Cost model. It is slightly less than the observed rate of decay and indicates that some adjustment in the factors used would make it an acceptable model for higher education facilities.

This model performs the best when individual buildings are analyzed. The five-year expenditure recommendations are the closest to the life cycle cost analysis of all the models. Within the timing limitations of the five-year increment, this model will provide the best timing for major maintenance activities as well as annual expenditures. Thus expenditure recommendations are most likely to represent the actual need and not take funds away from other needs. The chief facility officer is still responsible to know the specific projects that require maintenance funds, but the model will predict the amount required closely.

5.2.4 BRCI Model

The BRCI model is designed to address the periodic expenditures required to maintain different major building components. It does not have limitations of building age because it is dependent on the predicted life of different building components and assumes that these components will be replaced, as recommended, within five years of the recommended replacement date. The analysis indicates a predicted building condition index of 20.8 or 22.9 less than the measured index. This under-predicts funding needs by a factor of two; the buildings would be in twice as worse shape had the model expenditures be followed. The model does not incorporate the effects of individual room renovations which may occur. Because the model depends on detailed facility data that is not known or well understood by university administrators, often the ones responsible for making major maintenance funding decisions. The model will not provide the sort of support that may be required in order to present a successful rationale for a large expenditure.

This model produced higher than necessary funding requirements for the six buildings studied in detail. The five-year funding recommendations had a high average of 156% above the life cycle cost analysis amounts to a low of 14% above. This resulted in an average five-year expenditure recommendation at 93% above the life cycle analysis or nearly double the requirements. Expenditure recommendations at this level will result in excess funds being available for facility maintenance activities and recommend redirection of limited university funds from other activities.' The excess expenditures will likely result in unneeded expenditures on facilities leading to construction disruptions and sub-optimal use of equipment.

The difference in predictions between the overall application of the model and the sub-sample is due to the length of BRCI model cycles and the ages of the buildings in the sub-sample. The six buildings studied in detail were young enough so that building elements with a life cycle greater than 40 years were not included in the study. These elements are often high cost and would result in greater expenditure recommendations in later years.

5.2.5 USA-CERL Constant Square Footage Model

The Constant Square Footage model was developed in 1986 by the United States Army - Construction Engineering Research Laboratory. This is the most simple model of the three square footage-based models which may also utilize building age, current replacement value, and space utilization. This model has an indefinite life but utilizes values derived from cyclical data and more complex versions, discussed elsewhere, that have an eighty-year life. Application of this model, through extrapolation of USA-CERL space types to NCES space types results in a predicted BCI of 15.4 or recommended under-funding of major maintenance expenditures over the study period. The constant funding model does not distinguish between years when more funding is needed to address higher cost maintenance needs, nor does it reduce recommendations for years when few expenditures are needed. This model under-predicts by 64% of measured need over the study period.

At the same time, the model under-predicts individual building quinquennial need between 60% and 11%, with an average shortfall of 33%. This short-fall results in insufficient funds being available when needed to perform both annual and major maintenance activities, which are cyclical. Thus the model recommends expenditures which will result in the gradual erosion of facility condition through under-spending.

The USA-CERL Constant Model is unaffected by building age but the selection of building types, similarity between Army and higher education facilities, may play an important role.

5.2.6 Facility Formula Funding Model

This model was studied because it is used by the Illinois Board of Higher Education to recommend annual expenditures by the public universities in Illinois for major maintenance and to determine adequacy of funding. This method resulted in a predicted building condition index of 11.2 versus an actual index of 43.7. This difference of 32.5 is nearly four times worse than predicted by the model. This is the result of the model utilizing 0.67% of CRV for annual expenditures, less than one-half the rule of thumb range. However, had the model been adjusted to reflect the assumption that the university would rehabilitate a facility once during the assumed 100-year live of the building then the predicted index would be 28.8 and the difference of 14.9 would be more similar to the MRT+ARM model.

The model consistently under-predicts individual building need more consistently against the life cycle cost analysis than any other model. The average high five-year recommendation is 11% below the life cycle analysis amount and goes down to 98% below. The average five-year prediction is 68% less than life-cycle analysis identifies. This will produce results similar to the Constant USA-CERL model, above. Facilities will have insufficient funds available for essential maintenance activities, which will be deferred to later years. The BCI will gradually increase, as demonstrated above, and result in failing facilities and unnecessary interruptions. This further justifies modification of the model or development of a way to incorporate the 100-year cycle with the total rehabilitation of buildings, during that time, as dictated by the model.

5.2.7 USA-CERL MRT Model

This USA-CERL MRT model is designed to identify the expenditures for major repair and replacement tasks in a facility. The model is similar to the USA-CERL Constant Cost model but adds the facility age as an input to address varying replacement needs. For the first several years of building life the MRT model recommends no expenditures because all building components are still within their useful life. As major equipment reaches the end of its useful life annual recommended expenditures increase or fall depending on the typical mix of building components for a space type. The MRT model is designed for facilities up to 80-years old.

This model was applied to the facilities in the sample. Since there were two buildings in the sample that exceeded 80 years in age by the end of the study period an adjustment was made to allow for the age of individual spaces to be reset after a significant renovation. This adjustment allowed most of the spaces to remain in the analysis and not drop out due to age. The MRT model recommended an average annual expenditure of 0.51% of CRV over the study period. This resulted in a predicted building condition index of 7.2, significantly less than the measured index of 43.7. It is also approximately 1/6 of the observed decay rate of facilities in the sample. This indicates that maintenance needs cannot be based solely on the replacement of major building components but requires other annual expenditures.

The comparison of this model against life cycle cost analysis to the six buildings studied in detail shows the widest variation. The model over-predicted five-year expenditure needs by 97% down to under-predicting by 100%. The first five-year recommendation by this model is zero. The average MRT model prediction versus the life-cycle analysis is a 27% under-prediction. This correlates with the BCI values which recognizes that some annual expenditures are required for good maintenance results.

5.3 Model Results vs. Simplicity and Data

The goal of a good model is to have it sufficiently robust so that it can be applied to a wide variety of physical conditions without need to make a special exception. A robust model may require a large amount of complex data in order to be sufficiently robust. Then the model is not used, because it is so complicated. The purpose of the model is defeated. Therefore, there is interest in a model that is simple enough to apply but accurate enough to provide meaningful results.

The buildings were evaluated using seven expenditure predictive methods which utilized limited, non-technical building data as model inputs. The resultant recommendations were compared with actual funding expenditures drawn from overall major maintenance budgets for the study period to arrive at a predicted building condition index which was then compared with field observed conditions.

The seven predictive expenditure methods are: depreciation methods (straight line), formula funding (age method), facility funding formula, BRCI, and square foot based life-cycle maintenance requiring three levels of data detail. The seven methods use data inputs as shown in Table 5.1 below. An eighth model utilized detailed architectural and engineering building data to produce comparative expenditures following life-cycle and value engineering methods typical of technical analysis.

TABLE 5.1

DATA ELEMENTS REQUIRED BY DIFFERENT PREDICTIVE METHODS

Method/Data	Age	CRV	Area	Use
Depreciation		X	X	
Age Method	X	X	X	
Formula		X	X	X
BRCI	X	X	X	
Constant		X	X	X
MRT	X	X	X	X
MRT + ADM	X	X	X	X

Two of seven methods use all data inputs. One method uses only two inputs. The remaining methods use three inputs. All inputs are non-technical in nature and may be maintained by university personnel who are not familiar with architecture or engineering to develop annual expenditure recommendations for major maintenance.

5.3.1 Depreciation Model

The depreciation model is used by for-profit organizations to depreciate capital assets such as buildings. It is primarily an accounting tool used to recognize planned asset consumption for tax purposes. It has few inputs. The model predictions can be reduced by increasing the percent of salvage value remaining in the building at the end of the 50-year depreciation life. This analysis assumed no salvage value at the end of the depreciation. A salvage value of 10% would then result in an error of 3%.

It is not a tool designed for making maintenance decisions. The straight line depreciation model is applied to each building using the inputs of current replacement value and square footage. The straight line (SLN) depreciation model was studied following the recommendations of Kraal (1992) instead of using other depreciation techniques which were either more complex or required more data.

5.3.2 Age Formula Funding

This model was developed by Sherman & Dergis for higher education in 1984. An application of the age formula was applied to the buildings in the sample. The formula uses the inputs of facility age, current replacement value, square footage and utilization. These are simple inputs that can be understood and maintained by non-technical people. However, no maintenance information is provided by the analysis or assistance in allocating funds in a way that will benefit facilities in general. Because the model under-estimates expenditures for major maintenance as measured by building observation it is not deemed a good predictor.

5.3.3 USA-CERL ARM+MRT Model

This model assumes that the USA-CERL annual maintenance (ARM) and major repair and replacement tasks (MRT) activities fall within those defined as major maintenance for higher education facilities. The model requires the application, and interpolation, of space types similar to the other USA-CERL models. This data, is non-technical in nature but is more detailed because it requires that the classification of all spaces be known at all times. Of all the models studied, it comes the closest to predicting the overall expenditure needs to control deferred maintenance and prevent its accumulation without seriously mis-predicting funding needs for individual buildings. The level of detail is required for other purposes in a university and thus demands little extra in order to accomplish the maintenance function.

5.3.4 BRCI Model

The BRCI model, developed by Biedenweg & Hudson in 1981, provides an approximate method to measure the cost of building maintenance via building components. It divides the building into component parts which have a specified life cycle and specified cost. The costs are determined over a fixed period. Recommendations to consider costs in five year intervals allow the facility officer some discretion as to the actual expenditure pattern but is designed to assure administrative approval for needed funds. The level of detail maintained in order to operate the model is moderate. The model can be made more complicated, creating the need for a totally separate database that tracks building systems. Such a step would remove the operation of the model from a non-technical administrator, and in the view of the author, threaten the validity of the results.

5.3.5 Constant Square Footage Model

The Constant Square Footage is the most simple model of three square footage-based models developed by the USA-CERL which may also utilize building age, current replacement value, and space utilization. This model has an indefinite life but utilizes values derived from cyclical data and more complex versions, discussed below, that have an eighty-year life. Application of this model, through extrapolation of USA-CERL space types to NCES space types results in under-funding of major maintenance expenditures over the study period. The constant funding model does not distinguish between years when more funding is needed to address higher cost maintenance needs, nor does it reduce recommendations for years when little expenditures are needed. This model under-predicts by 64% of measured need over the study period.

5.3.6 Facility Formula Funding

This model, developed by Bareither and used by the Illinois Board of Higher Education, predicts the amount of annual funding needed for major maintenance based on space utilization, current replacement value, and square footage. The Facility Formula Method is derived from a 100-year life with a complete renovation of the building occurring once. This effectively reduces the timeframe for this method to 50 years. This method, with its assumed total renovation of facilities still under-predicts expenditures to successfully control the accumulation of deferred maintenance. It is also subject to misuse by administrators, based on the author's experience, because there is no clear delineation of the facilities intended to be served by the method.

5.3.7 USA-CERL MRT Model

This model is a moderately complex version of the USA-CERL funding models. It uses standards similar to those identified in the BRCI method for identifying cyclical replacement of major building components. Then it translates that to a square footage value for particular space types. This study extrapolated USA-CERL space types to NCES space types, just as with the Constant Cost model, and analyzed buildings over the 80-year life of data provided. Thus, generic building information which an administrator would have and be familiar with provides acceptable information for the operation of the model.

5.4 Interpretation of Results

The goal has been to identify a predictive model which will provide accurate maintenance expenditure recommendations with little technical input data. The rationale for having a simple model is that administrators often do not have the technical understanding of building systems and are suspicious of the high costs required to maintain buildings. If an accurate model exists that utilizes data that an administrator is familiar with, then they might be more accepting of the expenditure recommendations. The models have ranged from those simple enough that an accountant, with a minor amount of information about a set of buildings, could develop an annual estimate to models that require detailed information about building components. A model which closely matches the results of either measured decay in a set of buildings or the life cycle cost analysis of a building should be accurate in predicting the year the funds are required as well as predicting the building that requires the funds. An accurate prediction of annual funding needs could also be made for all buildings in the aggregate as well as for sub-groups of buildings.

The USA-CERL ARM+MRT model does the best job in predicting expenditures to control the accumulation of deferred maintenance of all the models studied. It under-predicted the funds necessary for maintenance when building conditions were measured but it was the most accurate when compared on a building to building basis with life cycle cost analysis. Other methods may have had better results when compared to building condition comparisons but they had much higher error when compared to individual buildings. The level of detail for input data is large but not beyond typical university data holdings. The data used is also familiar to non-technical administrators who may be in greater control of university resources than the chief facilities officer.

The other USA-CERL methods, MRT and Constant, were less accurate and did not include some elements which the ARM+MRT method incorporated. While it can be argued that there are significant differences between US Army facilities and higher education facilities, the ARM+MRT model performed well at predicting annual major maintenance needs and predicting funds needed to control the accumulation of deferred maintenance.

The straight line method, as demonstrated by Kraal (1992), worked successfully on those facilities which were within its recommended application, i.e., generally of the same age and not greater than 50 years old. The model is easy to apply and predicts equal expenditures year after year without recognizing that individual buildings will require more in one year than another. Likewise, a group of buildings, constructed at different times, may also require more or less expended to control maintenance in any given year than would otherwise be predicted by a constant funding model. Overall, a depreciation model does not account for maintenance needs as a result of differing life cycles of building components and uses of buildings. The model only provides an appropriate funding when the mix of buildings is homogenous. When the mix of buildings is not homogenous in terms of age or space use there is a high likelihood that the expenditure needs will not match the recommended allocation of funds.

The age formula model is refined more than the depreciation model because it takes into account an increased need for maintenance expenditures as a building ages. This increased need is demonstrated by other, more detail intensive models. It has more accurate results when compared to the actual spending patterns of the data examined. There is less need for homogenous building characteristics because the model can be applied to individual buildings. It still may provide for a significantly higher expenditure than may be required for buildings that are old or significantly lower than may be required for buildings that are young depending on individual building characteristics.

The facility formula funding method, used by the Illinois Board of Higher Education to predict what each university should be spending annually on major maintenance efforts, does not recommend sufficient spending levels to keep deferred maintenance from increasing. Approximately twice as much should have been spent as the formula recommended. This matches with the overall premise that the formula only identifies funds necessary to renovate a building fully once every 100 years and assumes that the university will obtain and spend funds within that period to renovate the building in a single effort with a large expenditure. However, the selection of the buildings and or building systems to receive the annual major maintenance funds remains a difficult administrative choice when the buildings are of a similar age and the funds are limited by a formula which assumes all buildings and components have a homogeneous life. Understanding the formula's assumption that a major renovation occurs outside of the formula itself is often overlooked and easily ignored.

It is important to note that the assumption that once during a 100-year period a building will be identified for complete renovation is reasonable. However, removal of major maintenance funds over 99 of the other years as a result of the assumption shortchanges the building maintenance which could be occurring. A more reasonable approach would be to allow for funding based on a 50-year cycle and to adjust down annual allocations when the university is receiving funds for a complete building renovation.

5.5 Conclusions and Recommendations

Based on the results of this study it is possible to make some conclusions and recommendations on funding needs for higher education facilities. These recommendations address model complexity, the data required to operate the model, the apparent level of detail provided by the model, and the ability of the model to assist planners and non-technical people in measuring the long-term cost of a facility.

The simplicity of the model is important in order to promote use of the model. It should be simple enough so that it can be used without a great deal of practice or documentation. It should also work well with other data sets that must otherwise be maintained to manage a higher education facility. Because of the cyclic nature and size of major maintenance funding needs it is important that the model be easy to use to predict expenditure needs several years in advance, recognizing the variability of inflationary cost increases.

The data required is important relative to the level of detail needed and the familiarity of the input data for the individuals using the data or reviewing the model results. If an administrator managing several hundred million of dollars worth of higher education facilities is unfamiliar with the input units then that person is less likely to accept the results of the model, particularly if the result is large. Common data, which is familiar to several different administrative areas as well as useable as benchmark data with other institutions is preferable to unique data that does not lend itself to comparisons.

The level of detail is also important because of the naturally large numbers involved. Presentation of a multi-million dollar annual expenditure with little or no detail describing the purpose is dangerous when there is an interest of accountability. In terms of accountability of expenditures the allocation of expenditures to individual facilities or spaces is helpful in maintaining accounting systems which require this level of detail.

Justification of research overhead is one example of this. Generic numbers are often interpreted as applicable to all items equally while the reality of building major maintenance is that it is highly cyclic. The convenience of including factors which allow the identification of funds for major maintenance to be charged to a dedicated research facility or area provide a superior method to support the necessary overhead. The hazard of this application is that researchers and sponsors will recognize the cost of conducting research in buildings which are approaching major expenditures and demand the use of newer facilities in order to conduct their research. The use of a model which does not rely as heavily on the specifics of a particular facility but relies on the type of space used to conduct the research, and demanded by the research, is more appropriate for determining appropriate overhead charges.

5.5.1 USA-CERL Funding Model

Three funding models developed by the US Army Construction Engineering Research Laboratory for funding annual and major maintenance tasks were studied. The models consisted of two very different detail levels and result in an administrative orientation different in focus.

The first and second models utilized square footage information specific to a particular building type to recommend an annual expenditure. The square foot based models were developed from the detailed component-based model recognizing that particular building types were composed of different sets of building components.

The first model recognized only major replacement costs and did not include any on-going maintenance costs exclusive of operating costs. This resulted in an under-funding of maintenance needs and in average building maintenance costs less than those predicted by other methods. The model requires a moderate level of data in order to be used. These data are in the form of individual space types and sizes as well as building age and are typically understood by most administrators. The data are also maintained for other purposes on campus apart from facility operations and maintenance. This allows for increased credibility of the data.

The second model using the USA-CERL square foot based information included a constant factor representing on-going annual costs for building maintenance apart from daily operations. This model more accurately reflected the building needs compared to simpler formulaic models by identifying lower expenditure needs in early years as well as higher costs in years when major component replacements were required.

The models used in this study were adapted to conform with nationally recognized higher education space data types required for annual reporting. These were data elements which are familiar to university administrators. The model predicted sufficient levels of funding when compared to actual need. This model was consistent across building types and variations of model components. The model requires no more data than is already maintained by university administrators and can be operated annually, or at a different frequency, via a simple database program.

The third model, one of building component life-cycle cost, provided specific information about costs and when these costs should be incurred on a long-term basis. These predictions were based on specific building components and both industry and US Army maintenance standards. The model also provided specific cost information to allow value engineering during the design phase of a construction project. This model required a great deal of initial data in order to operate the model. Specific information about the type of component and quantity of material making up the component were necessary. The predictions of annual major maintenance expenditure were below the expenditures predicted by the simpler models. This could have been the result of omission of data from the model, a likely outcome when detailed initial data is not provided to the facility manager when the building is constructed or without expenditure for a detailed survey of facilities. In addition, the level of detail of the model requires data elements which are foreign to most higher education administrators, particularly those who are not educated in a technical background. This high level of detail and large quantity of data to operate the model makes it undesirable for an administrator making overall decisions for an institution.

All three models provided sufficient information, prior to the construction of a building, to measure the long-term costs of the building and the activities it supports. The first two models could be used in very early planning stages of the building when the form of the building is not yet known. This is extremely useful in determining the overall cost of an academic program. The third model could be used to determine the cost of an academic program after the building was completely designed. The usefulness is still good if the administration has committed itself to a new or renovated building or to the costs to design the building. The second model (ARM+MRT) is the only model which allows for long-term cost estimation at the building programmatic level.

5.5.2 BRCI Model

The BRCI (before the roof caves in) model recognizes the cyclic nature of building maintenance and provides a moderate amount of information to the administrator to justify large expenditures for maintenance. It has been tested over a fifteen year period by its creators and appears to have reasonable accuracy given correct initial inputs. The authors of the model have not clearly articulated the appropriate inputs for component costs nor component life cycles. Tests may have to be performed before a particular campus has developed component information which works without significant error.

5.5.3 Facility Formula Funding Model

The facility formula funding model, because it assumes 1/3 of a facility will not require major repairs, provides for insufficient funds to address major maintenance needs. The assumption that the indefinite-lived portions of the building will receive adequate maintenance between funding cycles is too great an assumption and allows administrators the ability to divert funds from maintenance activities to other, perceived more important, activities. As a result of the assumption, this model predicts fully one third less annual need that the other models and does not identify alternate fund sources. The added assumption that the institution will request and receive funds to essentially gut and restore the building during the one hundred year model period is naïve.

This model, as with the other constant and linear models, is simple to apply but provides little in the way of detailed information to justify large resource requirements.

5.5.4 Depreciation Models

The application of depreciation models is, and will continue to be, a reasonable method to identify funds necessary for an aggregate group of facilities. Kraal (1992) specifically recommended the use of the straight line depreciation method for overall application. This study concurs with that recommendation. The caveats identified by Kraal should also be heeded, i.e., application to a group of buildings which are of similar ages yield better results, use of the model beyond its normal life does not adequately predict funding needs, and the group of buildings should have generally similar construction. This last caution can be assumed to infer that disparate funds will be necessary for buildings of different overall construction and that prediction of those funding differences in more difficult than a simple model can predict.

The depreciation model is simple. Once a major maintenance funding factor is selected then it can be adjusted on an annual basis either by using the current replacement value of campus buildings or by the rate of inflation which is published annually. An administrator interested in knowing to a more definitive level what expenditure funds will be needed does not obtain adequate information from this model. Small expenditures are overshadowed by the preset recommendation and large cyclic expenditures are ignored. The data is familiar only so far as the buildings may appear to have an increasing replacement value as a result of inflation similar to other items in the economy. Increased building costs or value resulting from increases in technology and/or regulations are lost if the model is increased by the inflation rate. Another significant shortcoming of the model is that it does not reflect the cost of not completing some work in a scheduled year because it does not consider buildings as unique elements or maintenance as cyclic.

5.5.5 Age Formula Model

This model provides reasonable accuracy to administrators for overall funding needs as well as individual building funding needs following intermediate expenditures, when the hybrid method is used, for major maintenance. It allows for very small annual expenditures in the early years of a building. It recognizes that in the later years of a building that higher annual expenditures for major maintenance are necessary. It does not recognize the cyclic nature of building maintenance and as a result predicts that significant funds should be expended in later years when this is not generally the case.

The model exhibits many of the same problems of the depreciation models. It schedules annual major maintenance expenditures when the building is young and not likely to have major maintenance expenditures. It recommends funding in excess of the rules of thumb values for building ages 39 through 50 years. It cannot be adjusted to reflect the cost of not performing work. It does not consider different components in the buildings having different life cycles which contribute to the annual major maintenance costs. An administrator who requires more detail to justify a large allocation of funds will not find sufficient information in this model. Likewise, cost differences between different facility uses are not apparent. Information for program-based costs are not available. The data used by the model is simple and allows for quick annual recalculation of annual financial needs.

5.5.6 Recommended Model

The USA-CERL ARM+MRT model based on individual space utilization, age and square footage is recommended as the best model for predicting major maintenance expenditure needs for colleges and universities. It utilizes fundamental information already maintained by the institution which is also readily understood by non-technical and administrative personnel. It allows for funding predictions beyond 50 years and for intermediate renovations to buildings. It is associated with a more detailed database which can provide specific building component recommendations to technical staff. It can be easily adjusted to recognize the value of intermediate renovations to buildings and conversions of building space from one activity to another.

The model is the only one studied which provides specific information on future building maintenance costs when the building is in early planning stages, prior to knowing how the building will be equipped and operated. The model recognizes the cyclic nature of building component life. This allows for institutions to focus on obtaining sufficient funds in future years to address major replacement efforts to individual buildings or the an aggregate of buildings. The specifics of which building component to receive major maintenance attention are lost in the model. However, since the model is founded on a set of industry standards for building component life cycles the informed administrator may use this information to direct the funds appropriately.

5.6 Recommendations for Future Study

The accumulation of deferred maintenance at Eastern Illinois University is extremely high. When these facts were presented to other facility officers at Illinois universities the numbers were questioned as being inflated. Independent verification of the 1987 audit by external architects and engineers, and the rate of increase in deferred maintenance similar to a straight-line expenditure method, indicates that the numbers were not inflated and a relatively serious condition exists. External to this study, the author has made presentations to faculty, staff, and students (relative novices in facility issues), who while agreeing that there is a serious problem with deferred maintenance do not find building conditions intolerable which the objective measures indicate. This was consistent across the campus with faculty working in buildings with building condition indices ranging between 3 and 67. A separate survey of faculty and staff conducted in late 1995 also indicated moderate satisfaction with the condition of buildings.

The University also enjoys an apparent attractiveness to student applicants and regularly closes admissions prior to most other public universities in Illinois. If the premise that 62 percent of students select a university based on the appearance of the campus then the student body appears to be satisfied with the campus appearance, and extrapolating the condition of the buildings. Therefore the severity of deferred maintenance does not appear to be readily observed by normal building occupants and users.

This leads the author to ask the question, how much deferred maintenance can exist on a college or university campus, or more appropriately in a building, before it adversely affects the instruction, research, or service activity conducted within? What level of deferred maintenance is tolerable by building occupants? What level of deferred maintenance is not tolerable? How much work must be accomplished in order to move a building from the "not tolerable" state to the "tolerable" state? Are there specific building systems which are more sensitive to deferred maintenance than others? Are there differences between university types and how levels of deferred maintenance are tolerated? Does deferred maintenance become inured in the campus atmosphere to the point were virtually any level will be tolerated? Are there specific maintenance items which affect the perception of deferred maintenance more than others? Are particular maintenance activities better at preventing secondary maintenance problems than others?

In a draft paper sent to the author, Harvey Kaiser postulates that overall college and university facility funding for maintenance and operations, exclusive of expenditures for utilities, should be approximately 4.5% of current replacement value. Of the 4.5%, between 1.5% and 3.0% should be expended on major maintenance efforts with the balance expended on daily or annual maintenance needs. Thus between 33% and 67% of annual spending on annual and major maintenance should be for major (deferred) maintenance.

The USA-CERL recommendations provide a similar number for comparison. Over the eighty-year dataset provided for a "permanent general instruction building, P4" the average annual expenditure for major maintenance was .748 vs. 1.00 (1985$) for annual maintenance and operations. This recommendation approximates to 42% of expenditures for annual and major maintenance activities should be for major maintenance. This is within the levels the Kaiser postulates for the average college or university facility. However, this overall ratio against estimated current replacement values was only 1.63% of current replacement value or approximately 1/3 of Kaiser's recommendation. Does that mean that colleges and universities have higher maintenance costs than the "typical" buildings elsewhere in the US? Are US Army facilities considerably cheaper to maintain versus the norm in higher education? If the first question is true then there are economies which can be found that will assist in the controlling of costs in higher education in the future. If the later question is true then higher education should investigate what facility standards exist in the military and learn how to apply those standards to higher education.

Three of the models studied here address only major maintenance funding and do not consider annual maintenance funding. Annual maintenance, often called routine maintenance, includes "custodial services, unplugging of drains, replacements of light bulbs, cleaning and caulking of gutters, and the like - expenditures with a useful life of weeks or months rather than years." (Dunn, 1989) The USA-CERL models include a category of annual repair and maintenance (ARM) which does not include custodial services. Given the magnitude of this annual recommended expenditure it appears that the models include a significant amount for preventive maintenance of long-lived equipment.

Lastly, while this model appears to work successfully with the selected data, it has not been tested on external data. An application of the recommended model to data available at other universities should be studied in order to determine if the model is adequately robust for regular use.

5.7 Conclusion

The selection of an appropriate model to determine the funding needed in a given year for major maintenance efforts at colleges and universities is important from a cost control and planning perspective. In addition, an administrator must be aware of the overall financial needs of individual buildings prior to making decisions on how to expend identified resources. A simple technique to utilize existing and required space data is desirable in order to determine what overall costs are anticipated as well as in planning future expenditures when renovations change a given space from one use to another.

Direct application of a major maintenance funding model to determine expenditures still requires periodic inspection of facilities to determine the existing condition and effectiveness of annual maintenance and the funding model. This effort can be coordinated with other physical planning activities, such as required master planning efforts which are mandated by state boards such as Florida and Georgia, or external audits of accounting activities. Confirmation of both predicted deferred maintenance and the actual measure of deferred maintenance will provide university decision makers with the necessary review of its management history.

Responsible management of higher education resources necessitates that administrators consider the value and cost of physical assets, vertical and horizontal infrastructure, and manage those assets in such a way as to preserve the value for the campus. The value may be determined by the serviceability of the asset and by the direct cost relationship to reproduce the physical asset. As higher education is challenged by society to prove its cost structures and annual cost increases which typically exceed inflation, models and techniques to assist with the analysis and provide reasonable measures are necessary.

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APPENDIX A

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                                                        MAINTENANCE AND
REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS

PAGE   1
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                                                         DISCOUNT RATE:
          6% Mid-Year

                                                         LOCATION:
          Charleston, IL

                                                         DATE OF STUDY:
          June 1989

                                                         STUDY PERIOD:
          25

                                                         STUDY STARTS:
          0 YEARS BEFORE BENEFICIAL USE

                                                         BUILDING 25
YEARS OLD AT END OF STUDY

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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    2
| LOCATION: Charleston, IL             STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989            STUDY PERIOD: 25
YEARS                  |
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|                                                 |  |         PRESENT
VALUE OF ALL 25 YEAR           |  |               ANNUAL MAINTENANCE
AND REPAIR PLUS                   |
|                                                 |  |        MAINTANCE
AND REPAIR COSTS (d=6%)         |  |            HIGH COST REPAIR AND
REPLACEMENT COSTS                 |
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|                  COMPONENT DESCRIPTION                 |UM|           BY
RESOURCES           | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
REPLACEMENT AND HIGH COST TASKS    |
|                                                        |
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+                                                       |  |  LABOR  |
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MATERIAL   |EQUIPMENT|               | |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR   |  MATERIAL   |EQUIPMENT|
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|ARCHITECTURE                                           |  |       |
|        |           | |         |            |        |  |
|           |         |
|  ROOFING                                              |  |       |
|        |           | |         |            |        |  |
|           |         |
|    ROOF COVERING                                      |  |       |
|        |           | |         |            |        |  |
|           |         |
|      BUILTUP ROOFING                                |SF|  0.07572|
0.92534|  0.03786|      2.84781| |  0.00492|      0.03996|  0.00246| 28|
0.04938|       0.88359|  0.02469|
|        PLACE NEW MEMBRANE OVER EXISTING -BUILTUP |  |         |
|        |           | |         |            |           | 14|
0.02414|       0.87694|  0.01207|
|      MOD.BIT./THERMOPLASTIC                         |SF|  0.05022|
0.87593|  0.02512|      2.15106| |  0.00244|      0.04030|  0.00122| 20|
0.05659|       1.07625|  0.02829|
|      THERMOSETTING                                  |SF|  0.03450|
0.64799|  0.01725|      1.52397| |  0.00172|      0.02785|  0.00086| 20|
0.03683|       0.87694|  0.01841|
|      SLATE                                          |SF|  0.03361|
0.24622|  0.01680|      1.09949| |  0.00255|      0.01871|  0.00128| 70|
0.06885|       7.57359|  0.03442|
|      CEMENT ASBESTOS                                |SF|  0.03268|
0.57509|  0.01635|      1.40483| |  0.00248|      0.04370|  0.00124| 70|
0.05437|       0.94250|  0.02718|
|      TILE                                           |SF|  0.02843|
0.58736|  0.01420|      1.30919| |  0.00216|      0.04463|  0.00108| 70|
0.10169|       3.85323|  0.05084|
|      ROLL ROOFING                                   |SF|  0.13583|
1.09607|  0.06792|      4.54492| |  0.00750|      0.01932|  0.00375| 10|
0.04141|       0.93966|  0.02070|
|      SHINGLES                                       |SF|  0.04423|
0.57041|  0.02212|      1.69344| |  0.00263|      0.03005|  0.00131| 40|
0.04118|       0.93381|  0.02059|
|        REPLACE NEW OVER EXISTING - SHINGLED ROOF |  |         |
|        |           | |         |            |           | 20|
0.02996|       0.54477|  0.01498|
|      METAL                                          |SF|  0.02719|
0.26392|  0.01359|      0.95415| |  0.00207|      0.02005|  0.00103| 30|
0.36265|       2.72384|  0.18132|
|      FIBERGLASS RIGID STP. ROOF                     |SF|  0.04452|
3.44582|  0.02226|      4.57607| |  0.00227|      0.07791|  0.00114| 20|
0.04543|       7.54037|  0.02272|
|      CONCRETE,SEALED PANEL ROOF                     |SF|  0.08118|
0.31289|  0.04060|      2.37402| |  0.00617|       0.02377|  0.00309| 60|
0.06123|     30.17677|  0.03061|
|      CONCRETE,SEALED PANEL RF4                   |SF|  0.07522|
0.19812|  0.03760|      2.10790| |  0.00572|       0.01505|  0.00286|300|
0.04342|     30.17677|  0.02171|
|      CONCRETE SEALED POURED                      |SF|  0.18419|
1.45721|  0.09209|      6.13388| |  0.01400|       0.11072|  0.00700|500|
3.81056|     22.60318|  1.90528|
|      FIBERGLASS, RIGID ROOF                      |SF|  0.07443|
3.44582|  0.03721|      5.33555| |  0.00465|       0.07791|  0.00232| 20|
0.04133|      7.54037|  0.02066|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    3    |
| LOCATION: Charleston, IL                 STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989              STUDY PERIOD: 25
YEARS                              |
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|                                                 | |          PRESENT
VALUE OF ALL 25 YEAR           | |               ANNUAL MAINTENANCE
AND REPAIR PLUS                  |
|                                                 | |        MAINTANCE
AND REPAIR COSTS (d=6%)          | |             HIGH COST REPAIR AND
REPLACEMENT COSTS                |
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|               COMPONENT DESCRIPTION                   |UM|           BY
RESOURCES            | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
REPLACEMENT AND HIGH COST TASKS   |
|                                                 |
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|                                                 | |  LABOR   |
MATERIAL   |EQUIPMENT|                 | |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR   |  MATERIAL   |EQUIPMENT|
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|ARCHITECTURE                                     | |          |
|         |             | |          |             |        |   |
|            |            |
|  EXTERIOR WALL                                              |  |        |
|          |            | |          |           |         |   |
|            |            |
|    EXTERIOR FINISHES                                        |  |        |
|          |            | |          |           |         |   |
|            |            |
|       ADOBE First Floor                                    |SF|  0.07271|
1.00211|  0.07271|      2.80975| |  0.00552|       0.07614|  0.00552|300|
1.10968|       2.73712|  0.56362|
|       ADOBE Second Floor                                   |SF|  0.15229|
1.00211|  0.15229|      4.78807| |  0.01157|       0.07614|  0.01157|300|
1.24670|       2.73712|  0.63954|
|       ADOBE Third Floor                                    |SF|  0.21005|
1.00211|  0.21005|      6.22386| |  0.01596|       0.07614|  0.01596|300|
1.38333|       2.73712|  0.71513|
|       CLAY BRICK First Floor                               |SF|  0.00580|
0.00733|  0.00580|      0.15154| | -0.00044|       0.00056|  0.00044|500|
1.09213|       1.52801|  0.54607|
|       CLAY BRICK Second Floor                              |SF|  0.00989|
0.00733|  0.00989|      0.25310| |  0.00075|       0.00056|  0.00075|500|
1.21433|       1.52801|  0.60717|
|       CLAY BRICK Third Floor                               |SF|  0.01223|
0.00733|  0.01223|      0.31125| |  0.00093|       0.00056|  0.00093|500|
1.33640|       1.52801|  0.66820|
|       CLAY BRICK (WP/P) 1st Flr.                           |SF|  0.04424|
0.11193|  0.04424|      1.37592| |  0.00056|       0.00060|  0.00056|500|
1.12866|       1.63430|  0.58260|
|          REFINISH PAINTED CLAY BRICK EXT. WALL - 1S|  |         |
|          |            | |          |           |         |  8|
0.02825|       0.07972|  0.02825|
|       CLAY BRICK (WP/P) 2nd Flr.                           |SF|  0.07185|
0.11193|  0.07185|      2.16474| |  0.00108|       0.00060|  0.00108|500|
1.26750|       1.63430|  0.66034|
|          REFINISH PAINTED CLAY BRICK EXT.WALL - 2ND|  |         |
|          |            | |          |           |         |  8|
0.04417|       0.07972|  0.04417|
|       CLAY BRICK (WP/P) 3rd Flr.                           |SF|  0.09655|
0.11193|  0.09655|      2.87039| |  0.00141|       0.00060|  0.00141|500|
1.40608|       1.63430|  0.73788|
|          REFINISH PAINTED CLAY BRICK EXT.WALL - 3RD|  |         |
|          |            | |          |           |         |  8|
0.05969|       0.07972|  0.05969|
|       CONCRETE BRICK 1st Floor                             |SF|  0.00580|
0.00886|  0.00580|      0.15307| |  0.00044|       0.00067|  0.00044|500|
1.09213|       1.84689|  0.54607|
|       CONCRETE BRICK 2nd Floor                             |SF|  0.00989|
0.00886|  0.00989|      0.25463| |  0.00075|       0.00067|  0.00075|500|
1.21420|       1.84689|  0.60710|
|       CONCRETE BRICK 3rd Floor                             |SF|  0.01232|
0.00886|  0.01232|      0.31511| |  0.00094|       0.00067|  0.00094|500|
1.33640|       1.84689|  0.66820|
|       CONCRETE BRICK (WP/P) 1 Fl                           |SF|  0.04346|
0.11346|  0.04346|      1.35518| |  0.00050|       0.00071|  0.00050|500|
1.12866|       1.95319|  0.58260|
|          REFINISH EXTERIOR WALL - 1ST FLOOR           |  |         |
|          |            | |          |           |         |  8|
0.02825|       0.07972|  0.02825|
|       CONCRETE BRICK (WP/P) 2 Fl                           |SF|  0.07188|
0.11346|  0.07188|      2.16716| |  0.00108|       0.00071|  0.00108|500|
1.26750|       1.95319|  0.66034|
|        REFINISH PAINTED CONCRETE BRICK EXT.WALL-2|   |          |
|           |                | |         |           |          |  8|
0.04417|        0.07972|  0.04417|
|      CONCRETE BRICK (WP/P) 3 Fl                         |SF|  0.09655|
0.11346|  0.09655|       2.87192| |  0.00141|       0.00071|  0.00141|500|
1.40608|       1.95319|  0.73788|
|        REFIN.PAINTED CONC.BRICK EXT.WALL - 3RD FL|   |          |
|           |                | |         |           |          |  8|
0.05969|        0.07972|  0.05969|
|      STRUCTURAL CLAY TILE 1 Flr                         |SF|  0.00156|
0.05776|  0.00156|       0.09652| |  0.00012|       0.00439|  0.00012|500|
0.20150|      12.03802|  0.10075|
|      STRUCTURAL CLAY TILE 2 Flr                         |SF|  0.00515|
0.05776|  0.00515|       0.18568| |  0.00039|       0.00439|  0.00039|500|
0.23465|      12.03802|  0.11733|
|      STRUCTURAL CLAY TILE 3 Flr                         |SF|  0.00720|
0.05776|  0.00720|       0.23685| |  0.00055|       0.00439|  0.00055|500|
0.26767|      12.03802|  0.13384|
|      STRUC. CLAY TILE WP/P 1 Fl                         |SF|  0.03916|
0.16235|  0.03916|       1.28111| |  0.00017|       0.00443|  0.00017|500|
0.23803|      12.14432|  0.13728|
|        REFINISH PAINTED STRUCT.CLAY TILE EXT.WALL|   |          |
|           |                | |         |           |          |  8|
0.02825|        0.07972|  0.02825|
|      STRUC. CLAY TILE WP/P 2 Fl                         |SF|  0.06711|
0.16235|  0.06711|       2.07973| |  0.00072|       0.00443|  0.00072|500|
0.28782|      12.14432|  0.17050|
|        REFINISH PAINTED STRUCT.CLAY TILE EXT.WALL|   |          |
|           |                | |         |           |          |  8|
0.04417|        0.07972|  0.04417|
|      STRUC. CLAY TILE WP/P 3 Fl                         |SF|  0.09144|
0.16235|  0.09144|       2.77470| |  0.00103|       0.00443|  0.00103|500|
0.33735|      12.14432|  0.20352|
|        REFINISH PAINTED STRUCT.CLAY TILE EXT.WALL|   |          |
|           |                | |         |           |          |  8|
0.05969|        0.07972|  0.05969|
|      CONCRETE BLOCK First Floor                         |SF|  0.00153|
0.00507|  0.00153|       0.04306| |  0.00012|       0.00039|  0.00012|500|
0.20150|       1.05765|  0.10075|
|      CONCRETE BLOCK Second Flr.                         |SF|  0.00515|
0.00507|  0.00515|       0.13300| |  0.00039|       0.00039|  0.00039|500|
0.23465|       1.05765|  0.11733|
|      CONCRETE BLOCK Third Floor                         |SF|  0.00720|
0.00507|  0.00720|       0.18417| |  0.00055|       0.00039|  0.00055|500|
0.26767|       1.05765|  0.13384|
|      CONCRETE BLOCK (WP/P) 1 Fl                         |SF|  0.03919|
0.10967|  0.03919|       1.22932| |  0.00018|       0.00042|  0.00018|500|
0.23803|       1.16394|  0.13728|
|        REFINISH PAINTED CONCRETE BLOCK EXT.WALL -|   |          |
|           |                | |         |           |          |  8|
0.02825|        0.07972|  0.02825|
|      CONCRETE BLOCK (WP/P) 2 Fl                         |SF|  0.06711|
0.10967|  0.06711|       2.02704| |  0.00072|       0.00042|  0.00072|500|
0.28782|       1.16394|  0.17050|
|        REFINISH PAINTED CONCRETE BLOCK EXT.WALL -|   |          |
|           |                | |         |           |          |  8|
0.04417|        0.07972|  0.04417|
|      CONCRETE BLOCK (WP/P) 3 Fl                         |SF|  0.09144|
0.10967|  0.09144|       2.72201| |  0.00103|       0.00042|  0.00103|500|
0.33735|       1.16394|  0.20352|
|        REFINISH PAINTED CONCRETE BLOCK EXT.WALLS-|   |          |
|              |           | |          |                    |        |  8|
0.05969|       0.07972|  0.05969|
|     CONCRETE (WP/P) First Flr.                        |SF|  0.04886|
0.11221|  0.04886|      1.50807| |  0.00091|        0.00062|  0.00091|500|
3.84605|       5.91272|  1.94129|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    4     |
| LOCATION: Charleston, IL               STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989              STUDY PERIOD: 25
YEARS                              |
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|                                                  | |          PRESENT
VALUE OF ALL 25 YEAR          | |                  ANNUAL MAINTENANCE
AND REPAIR PLUS                   |
|                                                     |      MAINTANCE
AND REPAIR COSTS (d=6%)       | |                 HIGH COST REPAIR AND
REPLACEMENT COSTS                 |
|                                                  |
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|              COMPONENT DESCRIPTION               |UM|           BY
RESOURCES          | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
REPLACEMENT AND HIGH COST TASKS    |
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|                                                  | |  LABOR  |-     -
MATERIAL   |EQUIPMENT|              | |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR  |  MATERIAL   |EQUIPMENT|
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|       REFINISH CONCRETE EXTERIOR WALL - 1ST FLOO|  |           |
|             |         | |          |                    |         |  8|
0.02825|       0.07972|  0.02825|
|     CONCRETE (WP/P) Second Flr                       |SF|  0.07775|
0.11221|  0.07775|      2.33342| |  0.00153|        0.00062|  0.00153|500|
4.25568|       5.91272|  2.15443|
|       REFINISH CONCRETE EXTERIOR WALL - 2ND FLOO|  |           |
|             |         | |          |                    |         |  8|
0.04417|       0.07972|  0.04417|
|      CONCRETE (WP/P) Third Flr.                     |SF|  0.10301|
0.11221|  0.10301|      3.05511| |  0.00191|       0.00062|  0.00191|500|
4.66570|       5.91272|  2.36769|
|        REFINISH CONCRETE EXTERIOR WALL - 3RD FLOO|  |         |
|         |            | |           |             |        |  8|
0.05969|       0.07972|  0.05969|
|      STONE First Floor                              |SF|  0.00153|
0.01084|  0.00153|      0.04883| |  0.00012|       0.00082|  0.00012|500|
0.20150|       2.25879|  0.10075|
|      STONE Second Floor                             |SF|  0.00515|
0.01084|  0.00515|      0.13876| |  0.00039|       0.00082|  0.00039|500|
0.23465|       2.25879|  0.11733|
|      STONE Third Floor                              |SF|  0.00720|
0.01084|  0.00720|      0.18993| |  0.00055|       0.00082|  0.00055|500|
0.26767|       2.25879|  0.13384|
|      STUCCO First Floor                             |SF|  0.04068|
0.12745|  0.04068|      1.28965| |  0.00029|       0.00046|  0.00029|300|
0.27846|       1.20912|  0.15750|
|        REFINISH STUCCO EXTERIOR WALL - 1ST FLOOR |  |         |
|         |            | |           |             |        |  8|
0.02825|       0.09301|  0.02825|
|      STUCCO Second Floor                            |SF|  0.07089|
0.12745|  0.07089|      2.15278| |  0.00101|       0.00046|  0.00101|300|
0.33241|       1.20912|  0.19279|
|        REFINISH STUCCO EXTERIOR WALL - 2ND FLOOR |  |         |
|         |            | |           |             |        |  8|
0.04417|       0.09301|  0.04417|
|      STUCCO Third Floor                             |SF|  0.09679|
0.12745|  0.09679|      2.89287| |  0.00143|       0.00046|  0.00143|300|
0.40963|       1.20912|  0.23966|
|        REFINISH STUCCO EXTERIOR WALL - 3RD FLOORS|  |         |
|         |            | |           |             |        |  8|
0.05969|       0.09301|  0.05969|
|      TERRACOTTA First Floor                         |SF|  0.00228|
0.02053|  0.00228|      0.07713| |  0.00017|       0.00156|  0.00017|500|
0.35009|       4.27841|  0.17505|
|      TERRACOTTA Second Floor                        |SF|  0.00596|
0.02053|  0.00596|      0.16861| |  0.00045|       0.00156|  0.00045|500|
0.39819|       4.27841|  0.19910|
|      TERRACOTTA Third Floor                         |SF|  0.00805|
0.02053|  0.00805|      0.22056| |  0.00061|       0.00156|  0.00061|500|
0.44928|       4.27841|  0.22464|
|      WOOD, FINISHED 1 COAT 1 Fl                     |SF|  0.06242|
0.19167|  0.06242|      1.97489| |  0.00021|       0.00042|  0.00021|125|
0.33124|       1.15597|  0.18109|
|        REFINISH WOOD FINISHED (S.CT) EXT.WALL - 1|  |         |
|         |            | |           |             |        |  5|
0.02555|       0.07972|  0.02555|
|      WOOD, FINISHED 1 COAT 2 Fl                     |SF|  0.10615|
0.19167|  0.10615|      3.22427| |  0.00076|       0.00042|  0.00076|125|
0.35893|       1.15597|  0.20150|
|        REFINISH WOOD FINISHED (S.CT) EXT.WALL - 2|  |         |
|         |            | |           |             |        |  5|
0.04119|       0.07972|  0.04119|
|      WOOD, FINISHED 1 COAT 3 Fl                     |SF|  0.14579|
0.19167|  0.14579|      4.35682| |  0.00106|       0.00042|  0.00106|125|
0.44915|       1.15597|  0.25610|
|        REFINISH WOOD FINISHED (S.CT) EXT.WALL -3R|  |         |
|         |            | |           |             |        |  5|
0.05645|       0.07972|  0.05645|
|      WOOD, FINISH MULTI-CT 1 Fl                      |SF|  0.04357|
0.17934| 0.04357|      1.42421| |  0.00022|       0.00045|  0.00022|125|
0.34502|       1.22240|  0.19487|
|        REFINISH WOOD FINISHED (MULTI-CT) EXT.WALL|          |
|        |            | |         |             |         |  8|
0.03120|       0.13287|  0.03120|
|      WOOD, FINISH MULTI-CT 2 Fl                      |SF|  0.07194|
0.17934| 0.07194|      2.23472| |  0.00076|       0.00045|  0.00076|125|
0.37037|       1.22240|  0.21294|
|        REFINISH WOOD FINISHED (MULTI-CT)EXT.WALL |  |          |
|        |            | |         |             |         |  8|
0.04741|       0.13287|  0.04741|
|      WOOD, FINISH MULTI-CT 3 Fl                      |SF|  0.09668|
0.17934| 0.09668|      2.94159| |  0.00107|       0.00045|  0.00107|125|
0.46592|       1.22240|  0.27287|
|        REFINISH WOOD FINISHED (MULTI-CT) EXT.WALL|  |          |
|        |            | |         |             |         |  8|
0.06323|       0.13287|  0.06323|
|      WOOD SHAKES UNFINISH 1 Flr                      |SF|  0.00259|
0.01364|  0.00259|      0.08303| |  0.00020|       0.00104|  0.00020|125|
0.04355|       0.89023|  0.02178|
|      WOOD SHAKES UNFINISH 2 Flr                      |SF|  0.01384|
0.01364|  0.01384|      0.38459| |  0.00105|       0.00104|  0.00105|125|
0.06097|       0.89023|  0.03049|
|      WOOD SHAKES UNFINISH 3 Flr                      |SF|  0.02002|
0.01364|  0.02002|      0.55006| |  0.00152|       0.00104|  0.00152|125|
0.07813|       0.89023|  0.03907|
|      WOOD SHAKES FINISHED 1 Flr                      |SF|  0.07759|
0.20180|  0.07759|      2.41847| |  0.00039|       0.00119|  0.00039|125|
0.07735|       1.02310|  0.05571|
|        REFINISH WOOD SHAKES (FIN.) EXTERIOR WALL |  |          |
|        |            | |         |             |         |  5|
0.03106|       0.07972|  0.03106|
|      WOOD SHAKES FINISHED 2 Flr                      |SF|  0.13797|
0.20180|  0.13797|      4.14355| |  0.00210|       0.00119|  0.00210|125|
0.11154|       1.02310|  0.08106|
|        REFINISH WOOD SHAKES (FIN.) EXTERIOR WALL |  |          |
|        |            | |         |             |         |  5|
0.04728|       0.07972|  0.04728|
|      WOOD SHAKES FINISHED 3 Flr                      |SF|  0.18698|
0.20180|  0.18698|      5.54370| |  0.00303|       0.00119|  0.00303|125|
0.14469|       1.02310|  0.10563|
|        REFINISH WOOD SHAKES (FIN.)EXTERIOR WALL -|  |          |
|        |            | |         |             |         |  5|
0.06298|       0.07972|  0.06298|
|      ALUMINUM SIDING First Flr.                      |SF|  0.05882|
0.25643|  0.05882|      1.93684| |  0.00447|       0.01948|  0.00447| 80|
0.09759|       2.56439|  0.06100|
|      ALUMINUM SIDING Second Flr                      |SF|  0.11721|
0.25643|  0.11721|      3.60509| |  0.00891|       0.01948|  0.00891| 80|
0.13334|       2.56439|  0.08660|
|      ALUMINUM SIDING Third Flr.                      |SF|  0.16483|
0.25643|  0.16483|      4.96576| |  0.01252|       0.01948|  0.01252| 80|
0.16869|       2.56439|  0.11188|
|      ALUM. SIDING ANODIZED 1 Fl                      |SF|  0.00141|
0.01917|  0.00141|      0.05687| |  0.00011|       0.00146|  0.00011|100|
0.07319|       2.65740|  0.03660|
|      ALUM. SIDING ANODIZED 2 Fl                      |SF|  0.00675|
0.01917|  0.00675|      0.20013| |  0.00051|       0.00146|  0.00051|100|
0.09347|       2.65740|  0.04674|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    5    |
| LOCATION: Charleston, IL              STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989             STUDY PERIOD: 25
YEARS                                  |
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|                                                      |  |          PRESENT
VALUE OF ALL 25 YEAR                |  |                 ANNUAL MAINTENANCE
AND REPAIR PLUS                       |
|                                                      |  |       MAINTANCE
AND REPAIR COSTS (d=6%)          |  |                HIGH COST REPAIR AND
REPLACEMENT COSTS                     |
|                                                      |
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|                COMPONENT DESCRIPTION              |UM|            BY
RESOURCES          | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
REPLACEMENT AND HIGH COST TASKS        |
|                                                       |
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|                                                                LABOR
MATERIAL    |EQUIPMENT|              |  |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR   |   MATERIAL   |EQU. MENT|
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|       ALUM. SIDING ANODIZED 3 Fl                    |SF|  0.00971|
0.01917|  0.00971|      0.27930| |  0.00074|       0.00146|  0.00074|100|
0.11362|       2.65740|  0.05681|
|       STEEL (SELF-COATING) 1 Flr                    |SF|  0.00609|
0.04453|  0.00609|      0.07012| |  0.00046|       0.00338|  0.00046|150|
0.59007|       6.93581|  0.29504|
|       STEEL (SELF-COATING) 2 Flr                    |SF|  0.00918|
0.04453|  0.00918|      0.08309| |  0.00070|       0.00338|  0.00070|150|
0.66209|       6.93581|  0.33105|
|       STEEL (SELF-COATING) 3 Flr                    |SF|  0.01210|
0.04453|  0.01210|      0.09536| |  0.00092|       0.00338|  0.00092|150|
0.73385|       6.93581|  0.36693|
|       STEEL (PAINTED) First Flr.                    |SF|  0.04390|
0.14419|  0.04390|      1.39840| |  0.00070|       0.00372|  0.00070|150|
0.63817|       7.62674|  0.34314|
|        REFINISH STEEL (PAINTED) EXTERIOR WALL - 1|  |          |
|            |              | |           |                 |        | 10|
0.03875|       0.10630|  0.03875|
|      STEEL (PAINTED) Second Flr                          |SF|  0.06486|
0.14419|  0.06486|      1.99724| |  0.00114|       0.00372|  0.00114|150|
0.72540|       7.62674|  0.39566|
|        REFINISH STEEL (PAINTED) EXTERIOR WALL - 2|  |          |
|            |              | |           |                 |        | 10|
0.05563|       0.10630|  0.05563|
|      STEEL (PAINTED) Third Flr.                          |SF|  0.08541|
0.14419|  0.08541|      2.58444| |  0.00156|       0.00372|  0.00156|150|
0.81718|       7.62674|  0.45039|
|        REFINISH STEEL (PAINTED) EXTERIOR WALL -3R|  |          |
|            |              | |           |                 |        | 10|
0.07237|       0.10630|  0.07237|
|      GLASS BLOCK First Floor                             |SF|  0.00555|
0.07287|  0.00555|      0.21087| |  0.00042|       0.00554|  0.00042|300|
1.04013|      15.18704|  0.52007|
|      GLASS BLOCK Second Floor                            |SF|  0.00957|
0.07287|  0.00957|      0.31089| |  0.00073|       0.00554|  0.00073|300|
1.15713|      15.18704|  0.57857|
|      GLASS BLOCK Third Floor                             |SF|  0.01201|
0.07287|  0.01201|      0.37136| |  0.00091|       0.00554|  0.00091|300|
1.27400|      15.18704|  0.63700|
|      PLATE GLASS First Floor                             |SF|  0.01669|
0.49634|  0.01669|      0.94371| |  0.00127|       0.03771|  0.00127|150|
0.09906|      10.62960|  0.04953|
|      PLATE GLASS Second Floor                            |SF|  0.05220|
0.49634|  0.05220|      1.89540| |  0.00397|       0.03771|  0.00397|150|
0.12194|      10.62960|  0.06097|
|      PLATE GLASS Third Floor                             |SF|  0.07193|
0.49634|  0.07193|      2.42412| |  0.00547|       0.03771|  0.00547|150|
0.14469|      10.62960|  0.07235|
|      FORMICA-VINYL First Floor                           |SF|  0.00431|
0.02301|  0.00431|      0.13864| |  0.00033|       0.00175|  0.00033| 40|
0.02925|       0.79722|  0.01463|
|      FORMICA-VINYL Second Floor                          |SF|  0.02551|
0.02301|  0.02551|      0.70674| |  0.00194|       0.00175|  0.00194| 40|
0.04524|       0.79722|  0.02262|
|      FORMICA-VINYL Third Floor                           |SF|  0.03733|
0.02301|  0.03733|      1.02346| |  0.00284|       0.00175|  0.00284| 40|
0.06084|       0.79722|  0.03042|
|      ASBESTOS First Floor                                |SF|  0.00303|
0.02357|  0.00303|      0.10472| |  0.00023|       0.00179|  0.00023|100|
0.04862|       1.31541|  0.02431|
|      ASBESTOS Second Floor                               |SF|  0.01631|
0.02357|  0.01631|      0.46055| |  0.00124|       0.00179|  0.00124|100|
0.06643|       1.31541|  0.03322|
|      ASBESTOS Third Floor                                |SF|  0.02353|
0.02357|  0.02353|      0.65408| |  0.00179|       0.00179|  0.00179|100|
0.08424|       1.31541|  0.04212|
|      SYN. VENEER-PLASTER 1st Fl                          |SF|  0.04416|
0.09312|  0.04416|      1.35487| |  0.00043|       0.00125|  0.00043|160|
0.06486|       0.91680|  0.04646|
|         REFINISH SYTHETIC VENEER                         |  |          |
|            |              | |           |                 |        |  7|
0.02672|       0.05315|  0.02672|
|      SYN. VENEER-PLASTER 2nd Fl                          |SF|  0.09321|
0.09312|  0.09321|      2.75601| |  0.00243|       0.00125|  0.00243|160|
0.09738|       0.91680|  0.07064|
|        REFINISH SYTHETIC VENEER 2ND FLR.              |  |         |
|         |            | |         |                    |        |  7|
0.04241|       0.05315|  0.04241|
|      SYN. VENEER-PLASTER 3rd Fl                        |SF|  0.12903|
0.09312|  0.12903|      3.77940| |  0.00354|       0.00125|  0.00354|160|
0.12942|       0.91680|  0.09445|
|        REFINISH SYNTHETIC VENEER 3RD FLR.              |  |         |
|         |            | |         |                    |        |  7|
0.05717|       0.05315|  0.05717|
|      PORCELAIN PANEL First Flr.                        |SF|  0.02421|
0.08610|  0.02421|      0.68806| |  0.00184|       0.00654|  0.00184|125|
0.08260|       3.16098|  0.02753|
|      PORCELAIN PANEL Second Flr                        |SF|  0.04119|
0.08610|  0.04119|      1.11005| |  0.00313|       0.00654|  0.00313|125|
0.10390|       3.16098|  0.03463|
|      PORCELAIN PANEL Third Flr.                        |SF|  C.05045|
0.08610|  0.05045|      1.34017| |  0.00383|       0.00654|  0.00383|125|
0.12491|       3.16098|  0.04164|
|      ALUM. CORRG. PANEL 1st Flr                        |SF|  0.00403|
0.04059|  0.00403|      0.16481| |  0.00031|       0.00308|  0.00031| 60|
0.02074|       1.55458|  0.01037|
|      ALUM. CORRG. PANEL 2nd Flr                        |SF|  0.02326|
0.04059|  0.02326|      0.75679| |  0.00177|       0.00308|  0.00177| 60|
0.04971|       1.55458|  0.02486|
|      ALUM. CORRG. PANEL 3rd Flr                        |SF|  0.03383|
0.04059|  0.03383|      1.08228| |  0.00257|       0.00308|  0.00257| 60|
0.07080|       1.55458|  0.03540|
|      EXT. GYPSUM BRD-PNTD 1 Flr                        |SF|  0.07206|
0.18074|  0.07206|      2.23939| |  0.00037|       0.00180|  0.00037|100|
0.08843|       1.64360|  0.05902|
|        REFINISH EXTERIOR GYPSUM BOARD-PNTD FIRST |  |         |
|         |            | |         |                    |        |  4|
0.02276|       0.05315|  0.02276|
|      EXT. GYPSUM BRD-PNTD 2 Flr                        |SF|  0.13857|
0.18074|  0.13857|      4.13966| |  0.00199|       0.00180|  0.00199|100|
0.11682|       1.64360|  0.07795|
|        REFINISH EXTERIOR GYPSUM BOARD-PNTD SECOND|  |         |
|         |            | |         |                    |        |  4|
0.03806|       0.05315|  0.03806|
|      EXT. GYPSUM BRD-PNTD 3 Flr                        |SF|  0.19473|
0.18074|  0.19473|      5.74428| |  0.00288|       0.00180|  0.00288|100|
0.15060|       1.64360|  0.10241|
|        REFINISH EXTERIOR GYPSUM BOARD-PNTD FIRST |  |         |
|         |            | |         |                    |        |  4|
0.05311|       0.05315|  0.05311|
|      EXT.GYPSUM BRD-COVERED 1Fl                        |SF|  0.19753|
2.38087|  0.19753|      7.67464| |  0.00039|       0.00198|  0.00039|100|
0.12397|       1.80172|  0.09456|
|        REFINISH EXTERIOR GYPSUM BOARD COVERED FIR|  |         |
|         |            | |         |                    |        |  4|
0.06514|       0.79722|  0.06514|
|      EXT.GYPSUM BRD-COVERED 2Fl                        |SF|  0.27659|
2.38087|  0.27659|      9.79355| |  0.00201|       0.00198|  0.00201|100|
0.16229|       1.80172|  0.12349|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    6    |
| LOCATION: Charleston, IL                  STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989              STUDY PERIOD: 25
YEARS                            |
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|                                                   |  |         PRESENT
VALUE OF ALL 25 YEAR          | |                   ANNUAL MAINTENANCE
AND REPAIR PLUS                   |
|                                                   |  |      MAINTANCE
AND REPAIR COSTS (d=6%)        | |                 HIGH COST REPAIR AND
REPLACEMENT COSTS                 |
|                                                   |
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|                COMPONENT DESCRIPTION              |UM|             BY
RESOURCES           | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR   |
REPLACEMENT AND HIGH COST TASKS    |
|                                                   |
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|                                                   |  |  LABOR  |
MATERIAL   |EQUIPMENT|            | |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR  |   MATERIAL   |EQUIPMENT|
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|         REFINISH EXTERIOR GYPSUM BOARD-COVERED 2ND|  |         |
|          |            | |        |              |         |  4|
0.08468|       0.79722|  0.08468|
|       EXT.GYPSUM BRD-COVERED 3F1                   |SF|  0.34531|
2.38087|  0.34531|     11.63516| |  0.00290|       0.00198|  0.00290|100|
0.20035|       1.80172|  0.15216|
|         REFINISH EXTERIOR GYPSUM BOARD COVERED 3RD|  |         |
|          |            | |        |              |         |  4|
0.10396|       0.79722|  0.10396|
|       MASONITE PANEL, SEALED 1F1                   |SF|  0.00271|
0.00977|  0.00271|      0.08236| |  0.00021|       0.00074|  0.00021|100|
0.05766|       0.67764|  0.02883|
|       MASONITE PANEL, SEALED 2F1                   |SF|  0.01402|
0.00977|  0.01402|      0.38559| |  0.00107|       0.00074|  0.00107|100|
0.07645|       0.67764|  0.03822|
|       MASONITE PANEL, SEALED 3F1                   |SF|  0.02026|
0.00977|  0.02026|      0.55270| |  0.00154|       0.00074|  0.00154|100|
0.09498|       0.67764|  0.04749|
|       FIBERGLASS PANEL,RIGID 1F1                   |SF|  0.07296|
0.27673|  0.07296|      2.36120| |  0.00043|       0.00313|  0.00043|150|
0.06536|       2.24882|  0.04748|
|         REFINISH FIBERGLASS PANELS RIGID FIRST FLO|    |        |
|        |           | |         |                |           |
0.02276|       0.07972|  0.02276|                                              |  4|
|       FIBERGLASS PANEL,RIGID 2Fl                               |SF|  0.14670|
0.27673|  0.14670|      4.46798| |  0.00260|      0.00313|  0.00260|150|
0.09144|       2.24882|  0.06526|
|         REFINISH FIBERGLASS PANELS, RIGID SECOND F|    |        |
|        |           | |         |                |           |
0.03806|       0.07972|  0.03806|                                              |  4|
|       FIBERGLASS PANEL,RIGID 3Fl                               |SF|  0.20681|
0.27673|  0.20681|      6.18529| |  0.00380|      0.00313|  0.00380|150|
0.12292|       2.24882|  0.08856|
|         REFINISH FIBERGLASS PANEL, RIGID THIRD FLO|    |        |
|        |           | |         |                |           |
0.05311|       0.07972|  0.05311|                                              |  4|
|  EXTERIOR DOORS
|        |           | |         |            | |        |
|           |           |                      |           |  |
|    METAL DOORS
|        |           | |         |            | |        |
|           |           |                      |           |  |
|       ALUMINUM (PLAIN/ANODIZED)                                |CT|  0.83772|
86.51166|  0.83772|   108.96247| |  0.06365|      6.57320|  0.06365| 65|
2.23574|    332.17500|  2.23574|
|       AL. (P&L) FRAME/DOOR                                     |CT|  1.23205|
91.04545|  1.23205|   124.06426| |  0.09361|      6.91768|  0.09361| 65|
2.73004|    410.98352|  2.73004|
|       AL. SLIDING EXT.(P&A) DOOR                               |CT|  1.55563|
216.03735|  1.55563|   257.72825| |  0.11820|     16.41463|  0.11820|
65|  2.73004|   1063.43727|  1.36502|
|       AL.(WOOD CORE) EXT. DOOR                                 |CT|  1.23205|
89.32321|  1.23205|   122.34203| |  0.09361|      6.78682|  0.09361| 65|
2.73004|    483.64680|  2.73004|
|       AL.(INSUL)P&A EXT. DOOR                                  |CT|  1.23205|
89.32321|  1.23205|   122.34203| |  0.09361|      6.78682|  0.09361| 65|
2.73004|    478.33200|  2.73004|
|       STEEL (PAINTED)                                          |CT|  1.46797|
62.26486|  1.46797|   104.20468| |  0.11154|      4.73092|  0.11154| 80|
2.59350|    156.36142|  2.59350|
|       STEEL PAINTED EXT. DOOR                                  |CT|  2.11931|
66.79865|  2.11931|   127.34746| |  0.16103|      5.07539|  0.16103| 80|
3.14685|    235.07626|  3.14685|
|       ST. SLIDING PNTD EXT. DOOR                               |CT|  1.91728|
133.48395|  1.91728|   188.26074| |  0.14568|     10.14218|  0.14568|
80|  3.14685|    887.14642|  1.78183|
|       ST.(INSUL CORE)PNTD EXT.DR                               |CT|  2.11931|
65.07642|  2.11931|   125.62523| |  0.16103|      4.94454|  0.16103| 80|
3.14685|    302.51842|  3.14685|
|       STEEL (UNPAINTED)                                        |CT|  0.49804|
51.43265|  0.49804|    64.78004| |  0.03784|      3.90788|  0.03784| 80|
2.26369|    182.03190|  2.26369|
|       ST.(GLASS)UNPNTD EXT. DOOR                               |CT|  0.89239|
55.96644|  0.89239|    79.88237| |  0.06780|      4.25236|  0.06780| 80|
2.73004|    276.36960|  2.73004|
|       ST.SLIDING UNPNTD EXT DOOR                               |CT|  0.69038|
126.67559|  0.69038|   145.17788| |  0.05246|      9.62488|  0.05246|
80|  2.73004|   1058.97390|  1.36502|
|       ST.(INSUL)UNPNTD EXT. DOOR                               |CT|  0.89242|
54.24421|  0.89242|    78.16093| |  0.06781|      4.12150|  0.06781| 80|
2.73004|    357.42030|  2.73004|
|    FULLY GLAZED DOORS                                           |  |         |
|          |          | |          |              |         |  |
|              |        |
|       ALUMINIUM FRAME                                       |CT|  1.23295|
90.73487|  1.23295|   123.77794| |  0.09368|       6.89408|  0.09368| 65|
2.23574|    495.60510|  2.23574|
|       GLAZED AL.SLIDING EXT.DOOR                            |CT|  1.06954|
63.91211|  1.06954|    92.37590| |  0.08126|       4.85607|  0.08126| 65|
5.63216|    797.22000|  2.81608|
|       WOOD FRAME (PAINTED)                                  |CT|  1.51636|
111.82262|  1.51636|   155.14490| |  0.11521|       8.49634|  0.11521|
50|  2.35677|    153.64422|  2.35677|
|       GLAZED WOOD SLID. EXT. DR                             |CT|  1.67663|
76.23211|  1.67663|   124.13338| |  0.12739|       5.79215|  0.12739| 50|
5.79892|    576.76210|  2.98284|
|    WOOD DOORS                                                   |  |         |
|          |          | |          |              |         |  |
|              |        |
|       HOLLOW CORE (PAINTED)                                 |CT|  2.05509|
87.52477|  2.05509|   146.23883| |  0.15615|       6.65018|  0.15615| 30|
2.58492|    246.71302|  2.58492|
|       HOL.CORE SLID. WOOD EXT.DR                            |CT|  2.51299|
66.99279|  2.51299|   138.78900| |  0.19094|       5.09015|  0.19094| 30|
6.05336|    265.47426|  3.23728|
|       SOLID CORE (PAINTED)                                  |CT|  1.57415|
54.84407|  1.57415|    99.81764| |  0.11960|       4.16708|  0.11960| 40|
2.58492|    279.93052|  2.58492|
|       SOLID SLID. WOOD EXT. DOOR                            |CT|  1.97101|
43.46268|  1.97101|    99.77441| |  0.14976|       3.30232|  0.14976| 40|
6.05336|    268.13166|  3.23728|
|       SOLID CORE GLASS PNTD EXT.                            |CT|  1.96853|
59.37786|  1.96853|   115.61882| |  0.14957|       4.51156|  0.14957| 40|
2.58557|    299.86102|  2.58557|
|    LOUVERED EXTERIOR DOOR                                       |  |         |
|          |          | |          |              |         |  |
|              |        |
|       METAL GRATED PNTD EXT.DOOR                            |CT|  2.27353|
19.08688|  2.27353|    84.04171| |  0.17274|       1.45023|  0.17274|150|
21.97979|    273.28702| 11.33121|
|       MET. GRATED UNPTD EXT.DOOR                            |CT|  0.25718|
4.64394|  0.25718|     5.72409| |  0.01954|      0.35285|  0.01954|150|
21.29716|    268.39740| 10.64858|
|       MET.WIRE MESH PNTD EXT. DR                            |CT|  2.66775|
14.49124|  2.66775|    90.70876| |  0.20270|       1.10105|  0.20270|150|
7.33475|    253.35652|  4.10780|
|       METAL WIRE PNTD EXT.DOOR                              |CT|  0.06588|
0.04829|  0.06588|     0.32499| |  0.00501|      0.00367|  0.00501|150|
6.45389|    248.46690|  3.22695|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    7    |
| LOCATION: Charleston, IL                 STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989              STUDY PERIOD: 25
YEARS                                    |
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|
                                                           | |       PRESENT
VALUE OF ALL 25 YEAR         | |                          ANNUAL MAINTENANCE
AND REPAIR PLUS                   |
|                                                          | |     MAINTANCE
AND REPAIR COSTS (d=6%)        | |                       HIGH COST REPAIR AND
REPLACEMENT COSTS                 |
|                                                             |
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|                COMPONENT DESCRIPTION                     |UM|          BY
RESOURCES              | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
REPLACEMENT AND HIGH COST TASKS   |
|                                                             |
+========+================+==========+                   |
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|                                                          | |  LABOR  |
MATERIAL    |EQUIPMENT|             | |  LABOR  |  MATERIAL
|EQUIPMENT|YRS|  LABOR   |  MATERIAL   |EQUIPMENT|
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|       AL. LOUVERED EXT. DOOR                          |CT|  2.90668|
65.18596|  2.90668|   148.22982| |  0.22085|      4.95286|  0.22085| 65|
6.04897|     637.35082|  3.23289|
|       STEEL LOUVERED EXT. DOOR                         |CT|  2.22556|
43.14644|  2.22556|   106.73062| |  0.16910|      3.27829|  0.16910| 80|
6.04897|     389.54827|  3.23289|
|       WOOD LOUVERED EXT. DOOR                          |CT|  4.39129|
132.78106|  4.39129|   258.24025| |  0.33365|     10.08877|  0.33365|
40|  6.04897|     390.21262|  3.23289|
|     EXTERIOR GATE                                        | |         |
|         |            | |         |              |            | |
|              |        |
|       ALUMINUM EXTERIOR GATE                          |CT|  1.93195|
56.17933|  1.93195|   111.37520| |  0.14679|      4.26853|  0.14679| 40|
2.25334|     528.02538|  1.22691|
|       STEEL EXTERIOR GATE                              |CT|  1.71975|
41.76476|  1.71975|    90.89798| |  0.13067|      3.17331|  0.13067| 65|
2.25334|     322.07688|  1.22691|
|       WOOD EXTERIOR GATE                              |CT|  2.82599|
296.42266|  2.82599|   377.16128| |  0.21107|     22.46422|  0.21107|
25|  2.25334|     595.78908|  1.22691|
|         REPLACE WOOD EXTERIOR GATE (WALK & DRIVEWA|  |           |
|         |           | |         |             |              | 25|
2.05286|     592.60020|  1.02643|
|       WROUGHT IRON EXT. GATE                          |CT|  1.82122|
44.54708|  1.82122|    96.57940| |  0.13838|      3.38471|  0.13838| 65|
2.25334|    322.07688|  1.22691|
|    SCREEN/STORM DOORS                             |  |       |
|             |         | |          |               |       |   |
|                |       |
|     ALUMINUM (PLAIN/ANODIZED)                      |CT|  4.66297|
205.78387|  4.66297|   330.75158| |  0.29977|     10.77457|  0.29977|
20|  2.23574|     199.30500|  2.23574|
|     PLASTIC                                        |CT|  3.27116|
190.00290|  3.27116|   277.66988| |  0.19333|     10.77457|  0.19333|
20|  2.26369|     150.14310|  2.26369|
|    ROLL-UP DOORS                                   |  |       |
|             |         | |          |               |       |   |
|                |       |
|     ST.FRAME-SINGLE (PAINTED)                      |CT|  6.15027|
186.92323|  6.15027|   362.63641| |  0.46730|     14.20252|  0.46730|
35|  4.84587|     221.68031|  2.67316|
|     ST. FRAME-DOUBLE (PAINTED)                     |CT| 11.21332|
238.54244| 11.21332|   558.90694| |  0.85199|     13.12458|  0.85199|
35|  5.38802|     558.71835|  3.21531|
|     AL. SINGLE ROLL-UP DOOR                        |CT|  5.24957|
347.59741|  5.24957|   497.57763| |  0.38920|     26.31204|  0.38920|
24|  4.84587|     169.52883|  2.67316|
|          REPLACE ALUMINUM SINGLE ROLL-UP DOOR      |  |       |
|             |         | |          |               |       | 24|
4.34542|     164.42663|  2.17271|
|     AL. DOUBLE ROLL-UP DOOR                        |CT|  9.93024|
395.31815|  9.93024|   679.02509| |  0.73436|     29.83109|  0.73436|
24|  5.38802|     600.24023|  3.21531|
|          REPLACE ALUMINUM DOUBLE ROLL-UP DOOR      |  |       |
|             |         | |          |               |       | 24|
4.34542|     589.61063|  2.17271|
|     WOOD SINGLE ROLL-UP DOOR                       |CT|  5.29347|
402.12330|  5.29347|   553.35768| |  0.38679|     30.39641|  0.38679|
16|  4.84587|     300.73796|  2.67316|
|          REPLACE WOOD SINGLE ROLL-UP DOOR          |  |       |
|             |         | |          |               |       | 16|
4.34542|     295.63575|  2.17271|
|     WOOD DOUBLE ROLL-UP DOOR                       |CT| 10.01675|
583.05987| 10.01675|   869.23842| |  0.72897|     43.97385|  0.72897|
16|  5.38802|     674.97960|  3.21531|
|          REPLACE WOOD DOUBLE ROLL-UP DOOR          |  |       |
|             |         | |          |               |       | 16|
4.34542|     664.35000|  2.17271|
|     AL.(ONE LEAF) SPRING DOOR                      |CT|  4.95076|
146.23572|  4.95076|   287.67883| |  0.37616|     11.11106|  0.37616|
48| 11.41516|     531.95833|  6.70848|
|     STEEL(ONE LEAF)SPRING DOOR                     |CT|  4.78961|
118.28170|  4.78961|   255.12099| |  0.36392|      8.98710|  0.36392|
70| 11.41516|     485.45383|  6.70848|
|     WOOD(ONE LEAF) SPRING DOOR                     |CT|  4.57136|
223.40911|  4.57136|   354.01296| |  0.34733|     16.97474|  0.34733|
32| 11.10961|     551.88883|  6.40293|
|  EXTERIOR WINDOWS                                  |  |       |
|             |         | |          |               |       |   |
|                |       |
|    OPERABLE WINDOWS                                |  |       |
|             |         | |          |               |       |   |
|                |       |
|     ALUMINIUM OPER. First Flr.                     |CT|  0.32053|
3.03597|  0.32053|    11.62619| |  0.02435|     0.23067|  0.02435| 75|
3.30634|     193.99020|  3.30634|
|       ALUMINIUM OPER. Second Flr                       |CT|  0.52468|
3.03597|  0.52468|     17.09732| |  0.03987|       0.23067|  0.03987| 75|
4.21782|     193.99020|  4.21782|
|       ALUMINIUM OPER. Third Flr.                       |CT|  3.56048|
3.03597|  3.56048|     98.45682| |  0.27053|       0.23067|  0.27053| 75|
5.12929|     193.99020|  5.12929|
|       STEEL FRAME-OPER(PNTD) 1Fl                       |CT|  0.98734|
3.89361|  0.98734|     32.10204| |  0.07502|       0.29584|  0.07502| 80|
3.59195|     345.72522|  3.59195|
|       STEEL FRAME-OPER(PNTD) 2Fl                       |CT|  4.57442|
3.89361|  4.57442|    134.58492| |  0.34757|       0.29584|  0.34757| 80|
5.95241|     345.72522|  5.95241|
|       STEEL FRAME-OPER(PNTD) 3Fl                       |CT|  6.65525|
3.89361|  6.65525|    194.03411| |  0.50567|       0.29584|  0.50567| 80|
7.70654|     345.72522|  7.70654|
|       WOOD FRAME-OPER(PNTD) 1 Fl                       |CT|  1.17807|
3.58083|  1.17807|     37.23819| |  0.08951|       0.27207|  0.08951| 50|
3.63199|     118.47991|  3.63199|
|       WOOD FRAME-OPER(PNTD) 2 Fl                       |CT|  4.56354|
3.44116|  4.56354|    133.82140| |  0.34674|       0.26146|  0.34674| 50|
5.99245|     118.47991|  5.99245|
|       WOOD FRAME-OPER(PNTD) 3 Fl                       |CT|  6.64436|
3.44116|  6.64436|    193.27059| |  0.50484|       0.26146|  0.50484| 50|
7.74658|     118.47991|  7.74658|
|       PLASTIC (WOOD CORE)FRM 1Fl                       |CT|  0.22500|
3.24829|  0.22500|      9.27830| |  0.01710|       0.24681|  0.01710| 75|
3.30634|     172.73100|  3.30634|
|       PLASTIC (WOOD CORE)FRM 2Fl                       |CT|  0.43510|
3.24829|  0.43510|     14.90910| |  0.03306|       0.24681|  0.03306| 75|
4.21782|     172.73100|  4.21782|
|       PLASTIC (WOOD CORE)FRM 3Fl                       |CT|  0.55453|
3.24829|  0.55453|     18.10970| |  0.04213|       0.24681|  0.04213| 75|
5.12929|     172.73100|  5.12929|
|       GLASS BLOCK-OPER First Flr                       |CT|  0.72272|
7.33066|  0.72272|     25.29751| |  0.05491|       0.55699|  0.05491|100|
3.02718|     353.07811|  3.02718|
|       GLASS BLOCK-OPER Second Fl                       |CT|  2.79475|
7.33066|  2.79475|     76.80821| |  0.21235|       0.55699|  0.21235|100|
4.47642|     353.07811|  4.47642|
|       GLASS BLOCK-OPER Third Flr                       |CT|  3.99383|
7.33066|  3.99383|    106.61718| |  0.30345|       0.55699|  0.30345|100|
5.31882|     353.07811|  5.31882|
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    8    |
| LOCATION: Charleston, IL                 STUDY STARTS 0 YEARS BEFORE
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                                                              STUDY PERIOD: 25
BENEFICIAL USE   DATE OF STUDY: June, 1989
YEARS                                   |
+=========================================================+==+==================
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                                                            |  |        PRESENT
|                                                           ANNUAL MAINTENANCE
VALUE OF ALL 25 YEAR                     | |
AND REPAIR PLUS                            |
                                                            |  |      MAINTANCE
|                                                           HIGH COST REPAIR AND
AND REPAIR COSTS (d=6%)                  | |
REPLACEMENT COSTS                          |
                                                            |
|
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+                                                       |UM|              BY
|               COMPONENT DESCRIPTION
RESOURCES                | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR    |
REPLACEMENT AND HIGH COST TASKS           |
|                                                             |
|                                                    |
+==========+==============+==========+
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+
                                                        |  |  LABOR  |
|
MATERIAL   |EQUIPMENT|                  | |  LABOR   |  MATERIAL
|EQUIPMENT|YRS|  LABOR   |   MATERIAL     |EQUIPMENT|
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+                                                    |CT|  0.58231|
|      ALUMINUM DOUBLE-OPER 1 Flr                  0.42295|  0.04424| 75|
5.56653|  0.58231|    21.17240| |  0.04424|
3.30634|    267.06870|  3.30634|                    |CT|  0.78646|
|      ALUMINUM DOUBLE-OPER 2 Flr                  0.42295|  0.05976| 75|
5.56653|  0.78646|    26.64354| |  0.05976|
4.21782|    267.06870|  4.21782|                    |CT|  0.89992|
|      ALUMINUM DOUBLE-OPER 3 Flr                  0.42295|  0.06838| 75|
5.56653|  0.89992|    29.68445| |  0.06838|
5.12929|    267.06870|  5.12929|                    |CT|  1.28736|
|      STEEL FRAME(DBL)-OPER 1 Fl                  0.54404|  0.09781| 80|
7.16025|  1.28736|    43.94027| |  0.09781|
3.60833|    494.80283|  3.60833|                    |CT|- 4.87445|
|      STEEL FRAME(DBL)-OPER 2 Fl                  0.54404|  0.37036| 80|
7.16025|  4.87445|   146.42315| |  0.37036|
5.96879|    494.80283|  5.96879|                    |CT|  6.95527|
|      STEEL FRAME(DBL)-OPER 3 Fl                  0.54404|  0.52846| 80|
7.16025|  6.95527|   205.87234| |  0.52846|                   -         -
7.72292|    494.80283|  7.72292|                    |CT|  1.92410|
|      WOOD FRAME(DBL)-OPER 1 Flr                  0.51854|  0.14619| 50|
6.82464|  1.92410|    61.79612| |  0.14619|
3.96973|    154.74572|  3.96973|                    |CT|  5.51118|
|      WOOD FRAME(DBL)-OPER 2 Flr                  0.51854|  0.41874| 50|
6.82464|  5.51118|   164.27901| |  0.41874|
6.33019|    154.74572|  6.33019|                    |CT|  7.59200|
|      WOOD FRAME(DBL)-OPER 3 Flr                  0.51854|  0.57684| 50|
6.82464|  7.59200|   223.72819| |  0.57684|
8.08432|    154.74572|  8.08432|                    |CT|  0.38412|
|      PLASTIC (WOOD)FRM-OPER 1Fl                  0.44097|  0.02919| 70|
5.80375|  0.38412|    16.09818| |  0.02919|
3.30634|    235.17990|  3.30634|                    |CT|  0.59422|
|      PLASTIC (WOOD)FRM-OPER 2Fl                  0.44097|  0.04515| 70|
5.80375|  0.59422|    21.72898| |  0.04515|
4.21782|    235.17990|  4.21782|
|      PLASTIC (WOOD)FRM-OPER 3Fl                         |CT|  0.71365|
5.80375|  0.71365|     24.92958| |   0.05422|        0.44097|  0.05422| 70|
5.12929|    235.17990|  5.12929|
|    INOPERABLE WINDOWS                                    | |       |
|            |            | |         |              |        |  |
|            |         |
|      ALUMINIUM-FIXED First Flr.                         |CT|  0.32053|
2.97200|  0.32053|     11.56221| |   0.02435|        0.22581|  0.02435| 75|
3.30634|    154.12920|  3.30634|
|      ALUMINIUM-FIXED Second Flr                         |CT|  0.52468|
2.97200|  0.52468|     17.03335| |   0.03987|        0.22581|  0.03987| 75|
4.21782|    154.12920|  4.21782|
|      ALUMINIUM-FIXED Third Flr.                         |CT|  0.63814|
2.97200|  0.63814|     20.07427| |   0.04849|        0.22581|  0.04849| 75|
5.12929|    154.12920|  5.12929|
|      STEEL FRAME(PNTD)-FXD 1 Fl                         |CT|  0.98734|
3.59932|  0.98734|     31.80774| |   0.07502|        0.27348|  0.07502| 80|
3.59195|    162.36462|  3.59195|
|      STEEL FRAME(PNTD)-FXD 2 Fl                         |CT|  4.57442|
3.59932|  4.57442|    134.29063| |   0.34757|        0.27348|  0.34757| 80|
5.95241|    162.36462|  5.95241|
|      STEEL FRAME(PNTD)-FXD 3 Fl                         |CT|  6.65525|
3.59932|  6.65525|    193.73981| |   0.50567|        0.27348|  0.50567| 80|
7.70654|    162.36462|  7.70654|
|      WOOD FRAME(PNTD)-FXD 1 Flr                         |CT|  2.16197|
4.06315|  2.16197|     65.83064| |   0.16427|        0.30872|  0.16427| 50|
4.13977|    287.37522|  4.13977|
|      WOOD FRAME(PNTD)-FXD 2 Flr                         |CT|  5.35206|
4.06315|  5.35206|    156.97146| |   0.40665|        0.30872|  0.40665| 50|
6.33019|    287.37522|  6.33019|
|      WOOD FRAME(PNTD)-FXD 3 Flr                         |CT|  9.26234|
4.29595|  9.26234|    268.92108| |   0.70376|        0.32641|  0.70376| 50|
8.08432|    287.37522|  8.08432|
|      PLASTIC (WOOD)FRM-FXD 1 Fl                         |CT|  0.22500|
3.53571|  0.22500|      9.56571| |   0.01710|        0.26864|  0.01710| 70|
3.30634|    298.95750|  3.30634|
|      PLASTIC (WOOD)FRM-FXD 2 Fl                         |CT|  0.43510|
3.53571|  0.43510|     15.19652| |   0.03306|        0.26864|  0.03306| 70|
4.21782|    298.95750|  4.21782|
|      PLASTIC (WOOD)FRM-FXD 3 Fl                         |CT|  0.55453|
3.53571|  0.55453|     18.39712| |   0.04213|        0.26864|  0.04213| 70|
5.12929|    298.95750|  5.12929|
|      GLASS BLOCK-FIXED 1st Flr.                         |CT|  0.72272|
7.33066|  0.72272|     25.29751| |   0.05491|        0.55699|  0.05491|100|
3.02718|    188.31931|  3.02718|
|      GLASS BLOCK-FIXED 2nd Flr.                         |CT|  2.80477|
7.33066|  2.80477|     77.05715| |   0.21311|        0.55699|  0.21311|100|
4.47642|    188.31931|  4.47642|
|      GLASS BLOCK-FIXED 3rd Flr.                         |CT|  4.00384|
7.33066|  4.00384|    106.86612| |   0.30421|        0.55699|  0.30421|100|
5.34482|    188.31931|  5.34482|
|      ALUMINIUM DBL-FXD 1st Flr.                         |CT|  0.58231|
5.47056|  0.58231|     21.07644| |   0.04424|        0.41566|  0.04424| 75|
3.30634|    207.27720|  3.30634|
|      ALUMINIUM DBL-FXD 2nd Flr.                         |CT|  0.78646|
5.47056|  0.78646|     26.54757| |   0.05976|        0.41566|  0.05976| 75|
4.21782|    207.27720|  4.21782|
|      ALUMINIUM DBL-FXD 3rd Flr.                         |CT|  0.89992|
5.47056|  0.89992|     29.58849| |   0.06838|        0.41566|  0.06838| 75|
5.12929|    207.27720|  5.12929|
|      STEEL FRAME(DBL)-FXD 1 Flr                       |CT|  1.28736|
6.70578|  1.28736|    43.48580| |  0.09781|        0.50951|  0.09781| 80|
3.60833|     219.75635|  3.60833|
|      STEEL FRAME(DBL)-FXD 2 Flr                       |CT|  4.87445|
6.70578|  4.87445|   145.96868| |  0.37036|        0.50951|  0.37036| 80|
5.96879|     219.75635|  5.96879|
|      STEEL FRAME(DBL)-FXD 3 Flr                       |CT|  6.95527|
6.70578|  6.95527|   205.41787| |  0.52846|        0.50951|  0.52846| 80|
7.72292|     219.75635|  7.72292|
|      WOOD FRAME(DBL)-FXD 1st Fl                       |CT|  2.33480|
8.00970|  2.33480|    74.71502| |  0.17740|        0.60858|  0.17740| 50|
3.96973|     406.00554|  3.96973|
|      WOOD FRAME(DBL)-FXD 2nd Fl                       |CT|  6.81895|
8.00970|  6.81895|   202.82701| |  0.51811|        0.60858|  0.51811| 50|
6.33019|     406.00554|  6.33019|
|      WOOD FRAME(DBL)-FXD 3rd Fl                       |CT|  9.42146|
8.00970|  9.42146|   277.18090| |  0.71585|        0.60858|  0.71585| 50|
8.08432|     406.00554|  8.08432|
|      PLASTIC (WOOD)DBL-FXD 1 Fl                       |CT|  0.38412|
6.23639|  0.38412|    16.53081| |  0.02919|        0.47384|  0.02919| 70|
3.30634|     425.18400|  3.30634|
|      PLASTIC (WOOD)DBL-FXD 2 Fl                       |CT|  0.59080|
6.23639|  0.59080|    22.06991| |  0.04489|        0.47384|  0.04489| 70|
4.21782|     425.18400|  4.21782|
|      PLASTIC (WOOD)DBL-FXD 3 Fl                       |CT|  0.71365|
6.23639|  0.71365|    25.36222| |  0.05422|        0.47384|  0.05422| 70|
5.12929|     425.18400|  5.12929|
|    LOUVERS & SHUTTERS                                 |  |         |
|          |          | |        |          |         |    |
|         |        |
|      WOOD LOUVER First Floor                          |CT|  2.94821|
60.71749|  2.94821|   144.94780| |  0.22401|       4.61335|  0.22401| 75|
5.95304|    101.88472|  5.95304|
|      WOOD LOUVER Second Floor                         |CT|  6.28543|
62.09945|  6.28543|   241.67427| |  0.47757|       4.71835|  0.47757| 75|
8.05853|    101.88472|  8.05853|
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|  See NOTES on the last page of this table for Explanation of Column
Headings
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MAINTENANCE AND REPAIR DATA BASE FOR LIFE-CYCLE COST ANALYSIS
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| EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE-CYCLE COST
ANALYSIS ($ PER UNIT MEASURE)
PAGE    9    |
| LOCATION: Charleston, IL                STUDY STARTS 0 YEARS BEFORE
BENEFICIAL USE   DATE OF STUDY: June, 1989               STUDY PERIOD: 25
YEARS                                     |
+============================================+==+=================
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|                                                     |  |       PRESENT
```

APPENDIX B

```
            VALUE OF ALL 25 YEAR         | |                   ANNUAL MAINTENANCE
            AND REPAIR PLUS                  |
            |                                                  |  |      MAINTANCE
            AND REPAIR COSTS (d=6%)       | |                 HIGH COST REPAIR AND
            REPLACEMENT COSTS                |
            |                                                  |
            +=================================+============+
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            |               COMPONENT DESCRIPTION              |UM|            BY
            RESOURCES          | UNIT COST  | |  ANNUAL MAINTENANCE AND REPAIR  |
            REPLACEMENT AND HIGH COST TASKS   |
            |                                                  |
            +=========+==============+=========+           |
            +=========+==============+=========+===+=========+=============+=========
            +
            |                                                  |  |  LABOR   |
            MATERIAL   |EQUIPMENT|              | |  LABOR  |  MATERIAL
            |EQUIPMENT|YRS|  LABOR  |  MATERIAL   |EQUIPMENT|
            +=================================================+==+=========+=======
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            +
            |      WOOD LOUVER Third Floor                     |CT|  7.15300|NBHFBEBQU BVUP
AQKM TFU EFOT U  ▮
AQKM FOUFS MBOHVBHF QDM
```